Navy Personnel Research and Development Center
San Diego, California 92152-7250 TN-96-45 July 1996

IMAT Team Reference Document Active Sonar Predictions

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATE COVERED
	July 1996	Interim

4. TITLE AND SUBTITLE
IMAT Team Reference Document Active Sonar Predictions

5. FUNDING NUMBERS
Program Element: 0603707N
Work Unit: 0603707N.L1772

6. AUTHOR(S)
Kristin Packer, Eleanor Holmes, Gregory M. Hale, Bill Beatty, Rich Loeffler, Sandra K. Wetzel-Smith

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Navy Personnel Research and Development Center
53335 Ryne Road
San Diego, CA 92152-7250

8. PERFORMING ORGANIZATION REPORT NUMBER
NPRDC-TN-96-45

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center, White Oak
10901 New Hampshire Avenue
Silver Spring, Maryland 20903-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Functional Area:	Training Research
Product Line:	Schoolhouse Training
Effort:	Schoolhouse Productivity

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*

The Interactive Multisensor Analysis Training (IMAT) system is used to teach complex conceptual knowledge and cognitive and procedural ASW skills. This computer-based instructional approach to underwater warfare is being used to improve training in aviation, surface and subsurface communities. This document is a reference guide for an audience of IMAT programmers, implementers, and curriculum developers. It discusses the capabilities and limitations of the Advanced Underwater Acoustic Modeling Project (AUAMP) model. The AUAMP has been implemented in the IMAT Active Sonar Prediction Module. The document is intended to be detailed enough to help the audience understand the AUAMP model. This understanding can help the audience develop lessons that teach useful concepts by using meaningful and realistic scenarios.

14. SUBJECT TERMS
Sonar, oceanography

15. NUMBER OF PAGES
112

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

Foreword

The Interactive Multisensor Analysis Training (IMAT) System Team Reference Document on Active Sonar Predictions was developed under the 6.3 Manpower, Personnel, and Training Advanced Technical Development Program Element 0603707N (Work Unit 0603707N.L1772). It was sponsored by the Naval Surface Warfare Center and was prepared under contract N00167-95-D-4007.

The goal of this work was to describe the Advanced Underwater Acoustic Modeling Project (AUAMP) model version 31.P. The details provided in this report are intended for use by IMAT programmers, implementors, and curriculum developers across the ASW communities.

Any questions regarding this report should be directed to Sandra K. Wetzel-Smith at Navy Personnel Research and Development Center, 53335 Ryne Road, San Diego, CA 92152-7250.

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Summary

The Interactive Multisensor Analysis Training (IMAT) system is an innovative computer-based approach to training for undersea warfare. One of the major elements of IMAT is its use of graphical representations of physical phenomena. A variety of models of these phenomena underlie the IMAT system. They are integrated with scientific visualization technologies to show users how three elements interact: the threat, the environment, and the equipment and its operators. The ability to demonstrate these interactions is one of the major strengths of IMAT, since students as well as experienced fleet personnel can better understand how and why these physical phenomena affect their on-the-job effectiveness.

To design and develop the many computer-based graphic representations, it is necessary for a variety of computer programmers, users, and instructional developers to work together effectively. They must refer to a common set of terms and display descriptions so they can illustrate and animate these phenomena.

The AUAMP model version 3.1P was developed by Science Applications International Corporation (SAIC). It is being used as the active sonar model in IMAT. Some modifications have been made to the AUAMP for the IMAT implementation of the model. These modifications, as well as descriptions and examples of a variety of displays, are included in this report. Also included are a generic lesson script, a brief review of some relevant physics concepts, and related active performance predictions software and how it fits into the IMAT system.

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Section One

Purpose

1.0 Purpose

This document was written to serve as a reference guide for IMAT programmers, implementors, and curriculum developers. It includes a discussion of the capabilities and limitations of the Advanced Underwater Acoustic Modeling Project (AUAMP) model, which has been implemented in the IMAT Active Sonar Prediction Module. The level of detail is intended to provide the audience with sufficient understanding of the model so that the lesson ware developed will contain meaningful and realistic scenarios for conveying useful concepts.

A sample demo script is provided in Appendix A. Additional information about AUAMP physics is contained in Appendix B. Changes to the standard AUAMP 3.1P software is described in Appendix C. A comment page is provided at the back of the document for recording readers' comments and suggestions concerning this document.

Section Two

Overview

2.0 Overview

2.1 Capabilities

The AUAMP model version 3.1P, which was developed by Science Applications International Corporation (SAIC), is being used as the active sonar model in IMAT. This range dependent model allows the user to calculate one-way TL, two-way TL, echo level, beam reverberation, beam noise, and signal excess for an area of interest. The model is valid for frequencies between 0 and 10,000 Hz.

Currently, this model is implemented to teach monostatic (i.e., source and receiver co-located) capabilities only. The performance of an active sonar system can be modeled for one transmission of one waveform type only. The user can specify a narrow band (CW) waveform or a wide band (HF) waveform. Depending on the type of waveform selected, the model will perform calculations to account for the doppler rejection of the "noise" and for the processing gain by the system.

The beam patterns that are supported are an omni-directional beam pattern and a cylindrical beam pattern. The cylindrical beam pattern is modeled as a steerable main lobe with a flat side lobe level; the transmit pattern has one main lobe and the receive pattern has multiple main lobes. The beam pattern information is used to properly calculate beam reverberation and beam noise.

Only certain databases have been implemented. A list of available databases can be found in Table 2-1. The user must ensure that reasonable values are input to the model for the case where a database does not exist. Caution should be used when generating runs to assess the performance of an actual system; the user must understand the inherent limitations of this implementation.

Table 2-1

Available Databases

Data	Version	Classification	File Name
Bathymetry[a] (DBDBC)	3.1	CONFIDENTIAL	bottom.globe
SAIC Seamount Database[a]	3.1	SECRET	seamount.globe
Low Frequency Bottom Loss[a]	2.0	CONFIDENTIAL	lfbl.globe
Sound Speed Profiles (Provinced GDEM)	3.1	UNCLASSIFIED	andprv.globe andtsc.globe
Bathymetry (DBDB5)	3.1	UNCLASSIFIED	bottom.globe
SAIC Seamount Database	3.1	UNCLASSIFIED	seamount.globe
Coastal Bathymetry	3.1	UNCLASSIFIED	coastl.globe
Bathymetry for the Med (DBDB2)		UNCLASSIFIED	
Low Frequency Bottom Loss (consolidated)	3.1	UNCLASSIFIED	lfbl.globe

[a]On an optical drive.

2.2 Limitations

2.2.1 General

The apparent "banding" in shadow zones in the full-field plot (see Figure 2-1) is due to the leakage of energy out of the duct; it is a result of the way ASTRAL calculates the leaked mode field. Further discussion of this effect is contained in Appendix B.

The model will stop executing after a range where it encounters a bottom depth of less than 50 meters or if the one-way transmission loss is more than 150 dB (internal parameter which can be modified).

The cylindrical array transmit beam pattern only has one side lobe level which results in the abrupt transition seen on the plan view SE plot. The use of actual beam pattern values (5° sampling) could be implemented.

The reverberation trace does not show the actual temporal variability seen in measured reverb. This results in the smooth beam reverb trace seen on the Echo/Noise/Reverb plot.

There is only one input value for DT. The model does not allow for separate reverb-limited and noise-limited thresholds. The user should enter a DT value appropriate to whether a noise-limited or reverb-limited condition exists at the range of interest.

2.2.2 Ducting Environments

The ASPM model can model propagation in and across surface ducts. Its limitations are seen when ducts and their properties are highly range dependent. Given the expected detection ranges for MF active sensors, ASPM will generally provide dependable results in environments containing surface ducts. The following are excerpts from the SAIC ASPM 4.0A User's Guide:

- *"Surface ducts may enter the problem only at the start of the calculation.... The surface duct may have characteristics that depend upon range (from profile to profile) and may eventually disappear. However, once gone, ASTRAL has no mechanism for re-ensonifying the surface duct if one should reappear."*
- *"Double ducts also may enter the problem only at the start of the calculation. Unlike surface ducts, the model will not recognize changes in the double ducts as a function of range. That is, the contribution from the double duct continues even after it has disappeared from the sound speed field."*

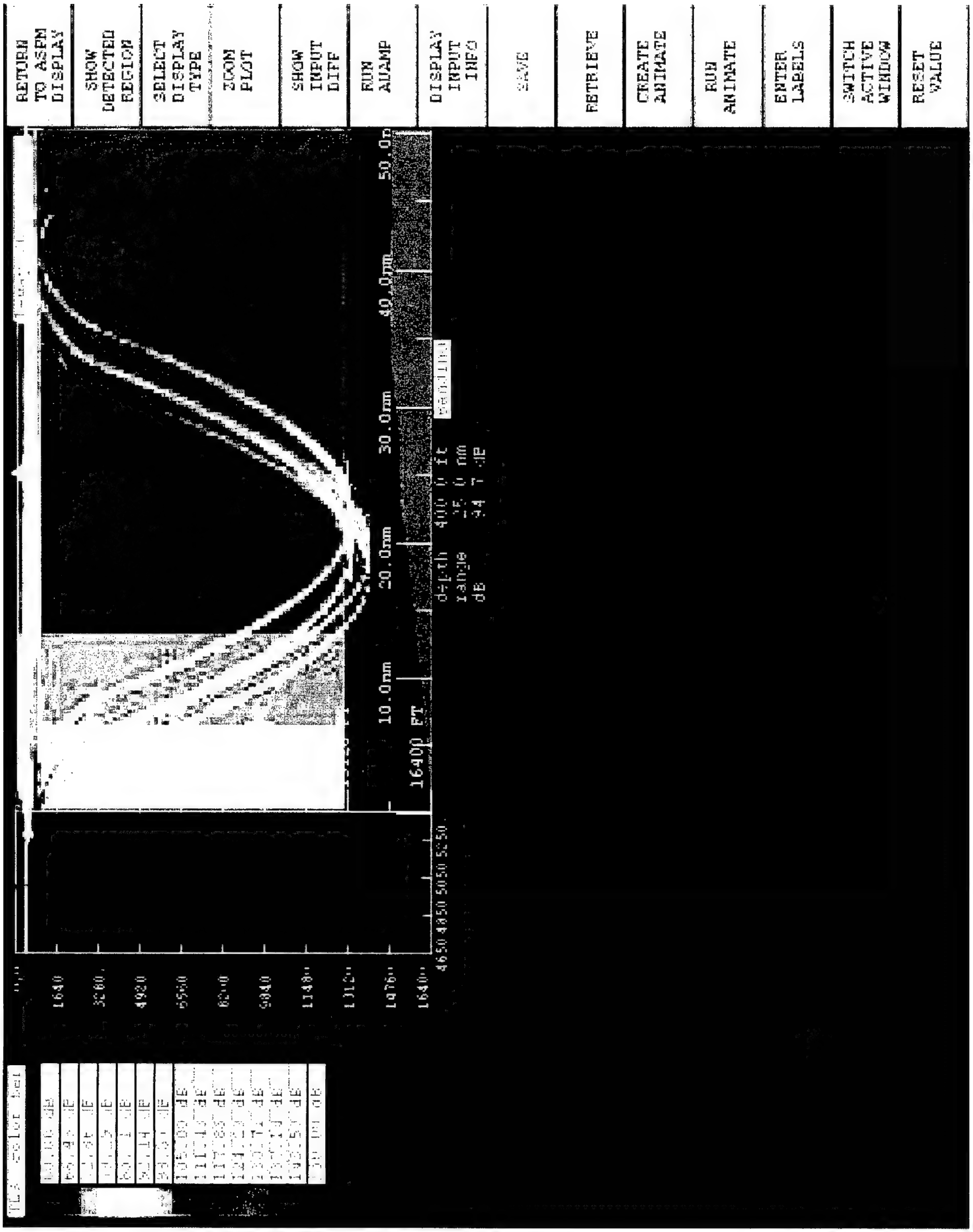


Figure 2-1. Banding due to duct leakage--ASTRAL model.

2.2.3 Shallow Water

The ASTRAL model contained in ASPM makes two assumptions, which leads to general concern about its performance in shallow water. However, the combination of short range (few bottom reflections) and high frequencies (kHz) alleviates the following general limitations:

- In water depths of about 10-15 times the wavelength of the transmitted signal, the TL could be too high. As a result, the reverberation level would be predicted lower than expected. At 3.5 kHz, this corresponds to water depths of about 25 feet.

- In very steep upslope environments (>3.5 degrees), ASTRAL may assign bottom-reflected energy to the wrong angle bins. This has very little effect on active predictions for two reasons. First, reverb is generally single reflection and its computations do not depend on properly modeling the out-going angle on a steep bottom. Secondly, modeled bottom slopes are rarely this steep, especially given the 2 or 5 minute database resolution.

2.3 Sonar Equation

2.3.1 Terminology

The terminology associated with the sonar equation varies from community to community. The notation used throughout this document is consistent with the notation used in Urick's Principles of Underwater Sound. The following terms are used throughout this document:

SL	Source Level
TL	Transmission Loss
TS	Target Strength
PG	Processing Gain
NL	Noise Level
DI	Directivity Index
RL	Reverberation Level
DT	Detection Threshold
SE	Signal Excess

2.3.2 Equations

The following equations are used in this document:

$$\text{Echo} = SL - 2TL + TS + PG$$

$$\text{Total Interference} = [(NL - DI) \oplus RL_{total}]$$

$$SE = \text{Echo} - \text{Total Interference} - DT$$

2.3.3 Additional Concepts

Two **independent** signals (such as reverberation and noise) are summed by the receiver. A power summation is not an addition of dB values. A power summation involves converting each quantity from its dB level to intensity level, summing the two intensity levels, and then converting back to dB level.

2.4 Model Software

Each model run is processed through four modules: ASERT, REVERB, BEAMFORM, and SONEQ. Figure 2-2 shows the model execution flow. Unlike the SAIC implementation of AUAMP, in the IMAT implementation the model is executed from ASERT through SONEQ each time. This figure also shows where in the process the various data files are created.

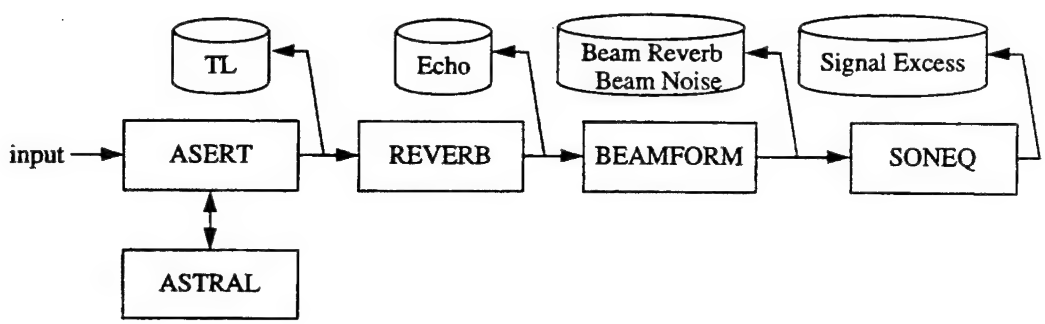


Figure 2-2. Model execution flow and data.

The original AUAMP code was ported from a SUN Workstation to the Silicon Graphics machine. Modifications to the configuration managed AUAMP have been documented in Appendix C. These modifications include creating a full-field display capability, hard-coding certain stand-alone model variables, and developing a new user interface.

2.4.1 ASERT

Transmission Loss (TL) is calculated in the ASERT module by the acoustic propagation model ASTRAL. ASTRAL calculates TL along a **single** line of bearing.

For a full-field plot, ASERT calls ASTRAL once to calculate the TL for the bearing of interest. For a plan view plot, ASERT calls ASTRAL a total of 72 times, once for each new radial. The environment is extracted for each radial at 1 nm increments.

Previously, the AUAMP model did not have the capability to display full-field (full water column) plots. The propagation loss was only calculated to a few depths in the water column. In order to display full-field plots in IMAT, the AUAMP code had to be modified to calculate TL to more depths. Currently, the water column is broken up into 101 equal depth increments. A depth

increment is calculated using the deepest depth along the chosen line of bearing and dividing by 101.

2.4.2 REVERB

The REVERB module calculates the bottom, surface, and volume reverberation in a 1° beam. A separate seamount reverberation calculation is made using the information contained in the SAIC seamount.globe file. The data from this run is then combined with the bottom reverberation data and is written to a new file. The bottom, surface, and volume reverberation density data is used in the beamform module to calculate the beam reverb components and the total beam reverb.

The echo level calculation is also performed in this module. For the echo level calculation the receive beam pattern is not considered. Only the transmit beam pattern is considered through the SL term.

2.4.3 BEAMFORM

Beam reverberation and beam noise are calculated in the BEAMFORM module. Previously, reverberation density components were calculated and displayed by the system. The code has since been modified to calculate and display beam reverb components. A complete discussion of the beam noise calculation is provided in paragraph 4.4.

2.4.4 SONEQ

The SONEQ module calculates SE. This calculation uses the echo level data calculated in the REVERB module, the beam reverb data and beam noise data calculated in the BEAMFORM module, and the user input DT value.

2.5 Databases

The user has the option of specifying a classified data run or an unclassified data run upon entry into the IMAT system. Table 2-1 (see page 7) indicates the databases currently implemented on the system.

Section Three

General Display Descriptions

3.0 General Display Descriptions

Table 3-1 indicates the type of data which is available after an AUAMP run and the format in which the data can be displayed. It doesn't matter if the run was initiated from the Active Sonar Prediction--full-field area or the Active Sonar Prediction--tactical view area. Throughout this document the term plan view is used in place of plan view plot; the plan view presentation is contained in the Active Sonar Predictions--tactical view display. A more detailed description of each display format is provided in the paragraphs which follow.

Table 3-1

Data Types and Display Formats

Data	Display Formats		
	Full-Field	XY Trace	Plan View
1-way TL	X	X	X
2-way TL	X	X	X
Echo	X	X	X
Beam Reverb Components	---	X	---
Echo/Noise/Reverb (ENR)	---	X	---
Signal Excess (SE)	X	X	X

3.1 Full-Field Display

The full-field plot shows model predictions for one bearing, all depths, and all ranges. Figure 3-1 is an example of a full-field echo plot. An echo level of 23.7 dB is predicted by the model for a target located along a bearing of 270°T (Src Horiz Steer), at depth of 338.9 ft, at a range of 26.9 nm, and for a source/receiver at 35° N, 20° W.

Each point on this plot should be interpreted in the manner just described. The data at each point is a prediction of what the echo level would be if the target were located at that point. Obviously, if a target were located at a different range and depth, the echo level would be different. It is incorrect to assume that the target is located at any specific range and depth in this plot; **the target icon acts as a reference point for discussion only**. The information listed above was not for the target icon position.

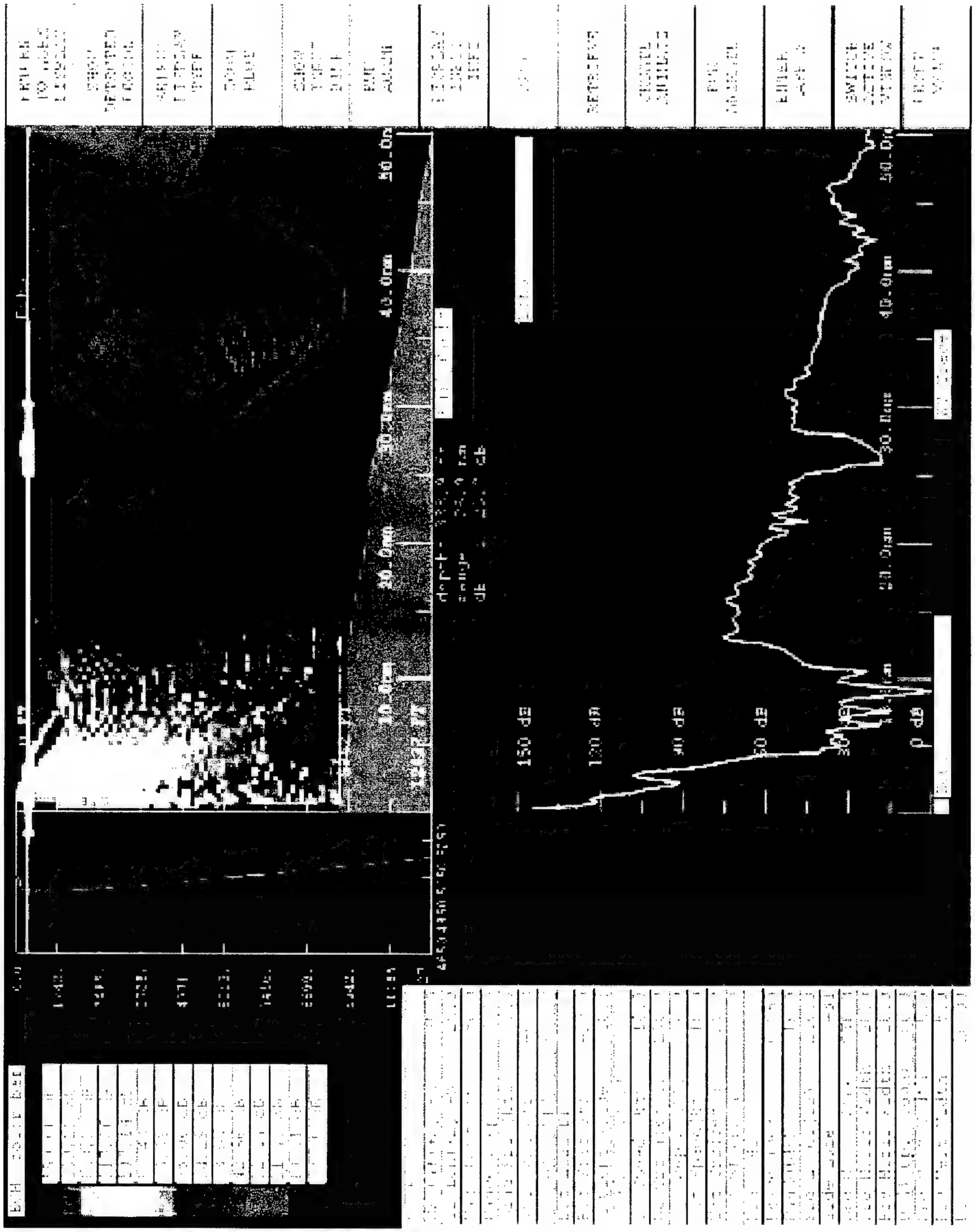


Figure 3-1. Echo level--Full field and XY trace.

3.2 XY Trace Displays

3.2.1 TL, Echo, and SE Traces

The xy plot format shows model output for one bearing, one depth, and all ranges. Figure 3-1 contains an example of an xy trace of echo level. The data on the xy plot corresponds to the data in the full-field plot at the target icon bar depth (white line extending across the display). The values on the full-field plot at a fixed depth will match the values on the xy plot for the same depth. In this case the depth is 338.9 ft.

3.2.2 Reverb Components, Beam Reverb, and Beam Noise Traces

The description in the paragraph above does not apply to the reverb data plotted on the Reverb Components display or the reverb and noise data plotted on the Echo/Noise/Reverb (ENR) display. Reverberation and noise data are a function of time, not a function of depth.

Reverberation and noise are shown as a function of range because the data is converted from time to range using the equation:

$$\text{Range} = (\text{speed of sound} * \text{2-way travel time})/2.$$

As an example, assume that the local speed of sound is 5,000 ft/s and the maximum range is 50 nm or approximately 300,000 ft. Rearranging the equation to solve for t, we see that the two-way travel time out to 50 nm is 120 seconds. In other words, if we listened to this receive beam for 2 minutes the reverb trace in Figure 3-2 would be traced out. This is also true for the noise data. The echo data can be interpreted as described above.

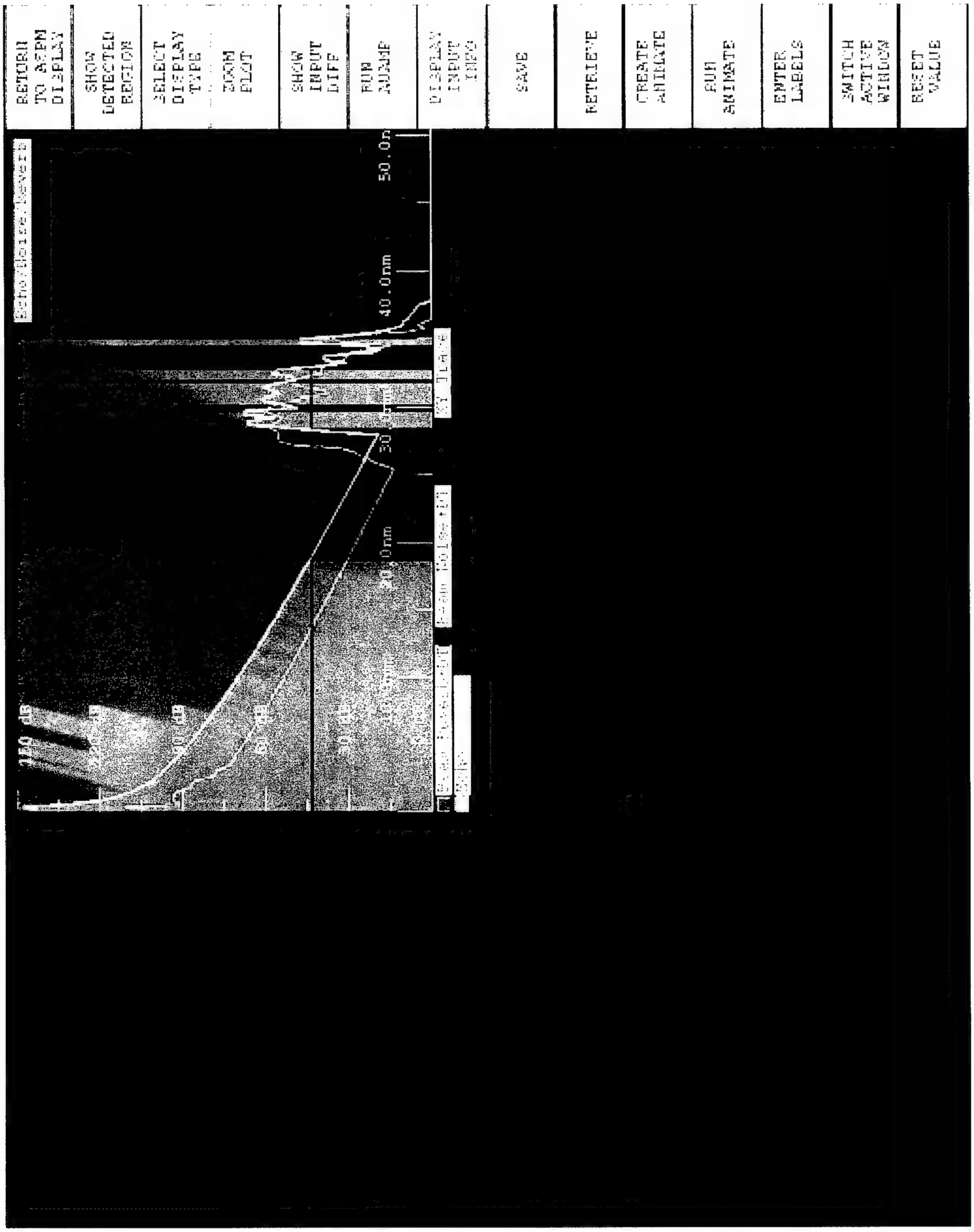


Figure 3-2. Echo/noise/reverb over 120 seconds.

3.2.3 Additional Clarification--Echo

One additional comment about the echo trace is necessary. It is important to realize that the echo xy trace does not represent the received echo in time. **In other words, the echo is not being received over the entire range!** An actual target echo return would be seen over a very small "range" (actually time as previously discussed). Figure 3-3 and Figure 3-4 demonstrate how the data on the ENR display should be interpreted. Figure 3-3 is an IMAT system display. A vertical line was added to this figure so that a comparison could be made with Figure 3-4. An actual system would receive the data displayed in Figure 3-4, showing an echo return for a target at 10 nm. The total interference curve in this figure is the power summation of the reverb and noise data in Figure 3-3.

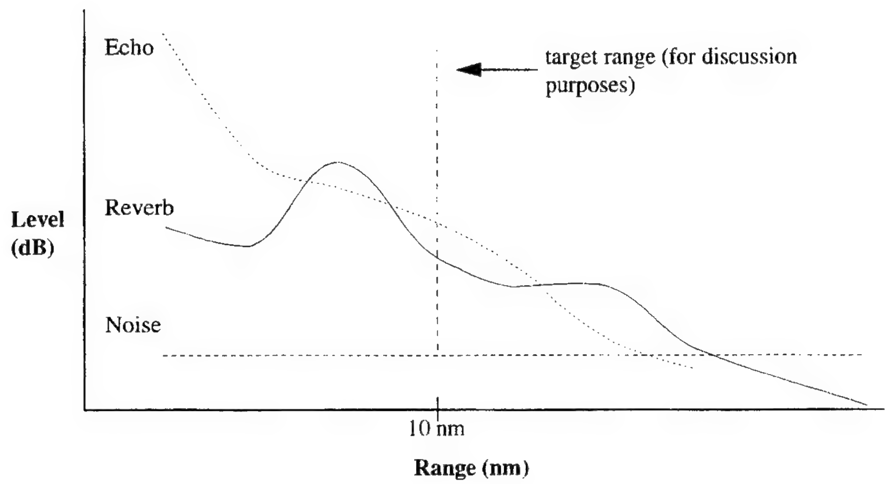


Figure 3-3. Echo/noise/reverb display.

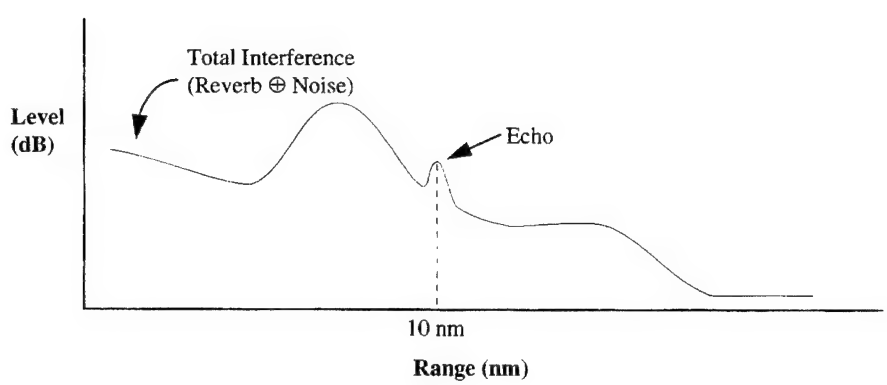


Figure 3-4. Data from one receive beam.

3.3 Tactical View Display

The tactical view display has four data display areas. Figure 3-5 is an example of the plan view display.

In the upper right corner of this figure is an Echo/Noise/Reverb Plot. This data is related to the SE data in the white sector indicator shown in the plot in the bottom right corner of this display. As the sector indicator is moved to different sectors on the SE display, the corresponding echo/noise/reverb data will be shown. As the user moves the sector marker in azimuth, the bathymetry slice plot will also change to represent the bathymetry in that slice.

In the bottom right corner of this display is a plan view SE plot. The data shown on this SE plot is valid for **one** source/receiver-target depth combination. If the performance at a different target and/or a different source/receiver depth is desired, the model must be rerun. The SE data is displayed for the depth of interest: the target depth.

The plot provides an indication of the ability of the monostatic platform to detect the target at the user input target depth only. Furthermore, it is easy to confuse the data displayed in this format with the data displayed on an actual sonar system display of similar appearance. The sonar system display cannot show data at a particular depth; it receives data as a function of time from all different depths.

As mentioned above, the plan view plot shows the performance of the system at **one** depth only. The top portion of Figure 3-6 is for a source/receiver at 50 ft and a target at 400 ft. In the bottom azimuth plot, the source/receiver has descended to a depth of 650 ft. The cursor readout indicates the target depth for each case which is 400 ft. For this environment and for a target at 400 ft, the system gets more coverage at the deeper depth. The effect of changes in depth to either of the two units (source/receiver or target) is often better represented on the full-field display. This plot also shows the ship's heading and the transmit sector center. The ship's heading is specified in the user input display as Own-Ship Course. The transmit sector center is specified as SRC Horizontal Steer. Own-ship position is at the center of the plot.

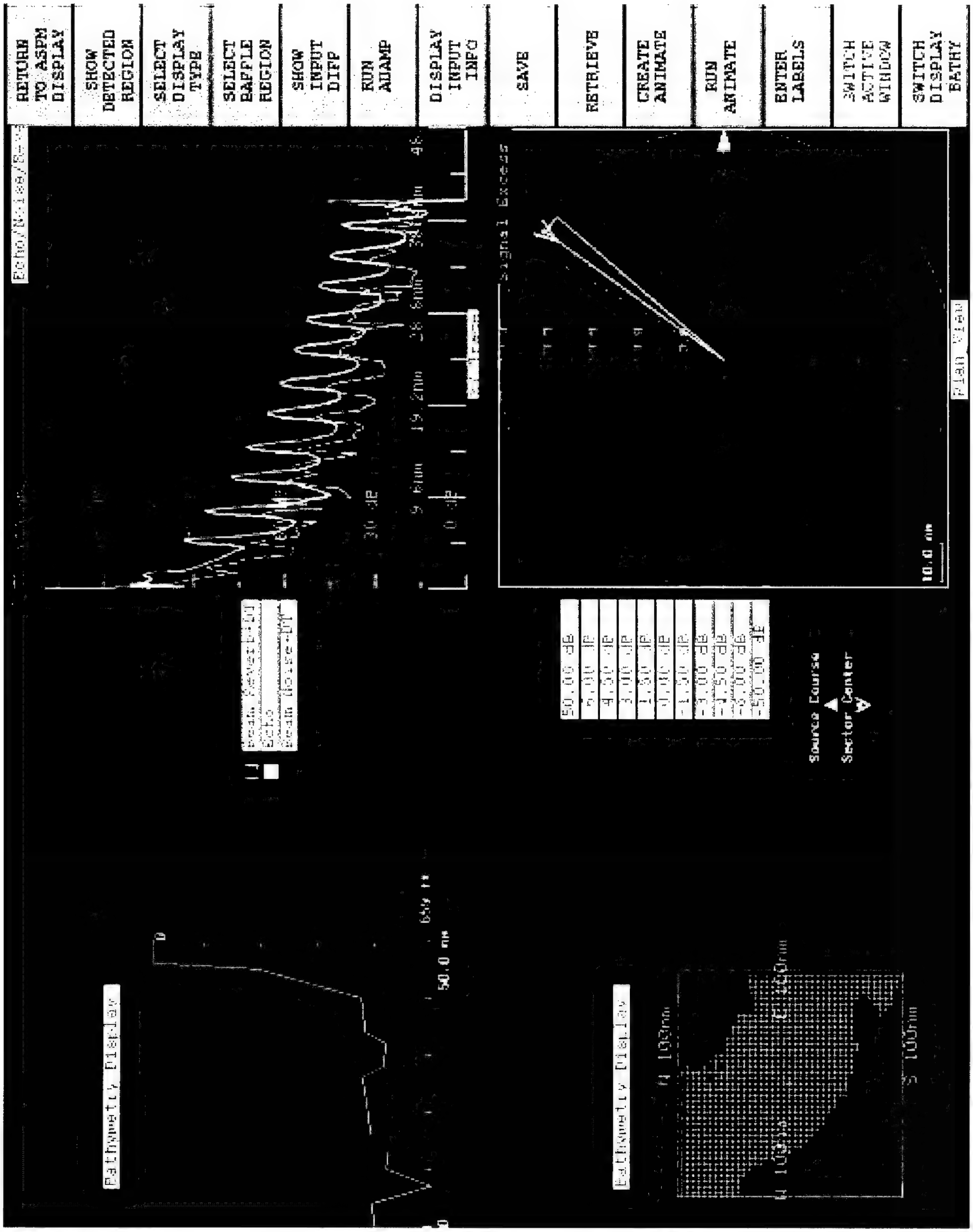


Figure 3-5. Plan view display.

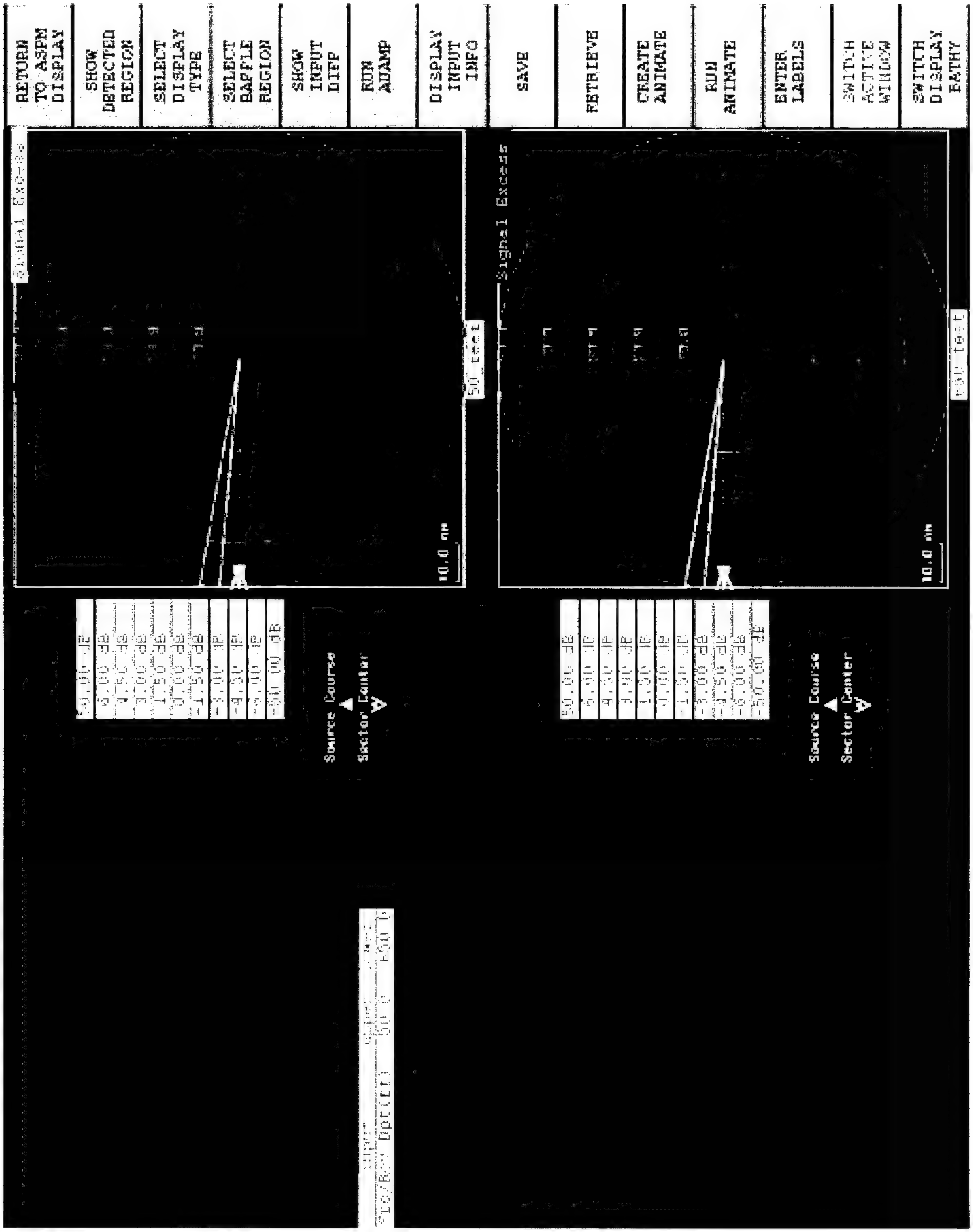


Figure 3-6. Signal excess--SRC/RCV depth change.

3.4 Display Format Summary

Table 3-2 summarizes how data is displayed in the different display formats:

Table 3-2

Displayed Data

Display Format	Bearing	Depth	Range
Full-field	1 bearing	max depths	max ranges
Plan View (azimuth)	all bearings	1 depth	max ranges
XY Trace	1 bearing	1 depth	max ranges

The relationship between the displays is as follows:

- For any one run, the full-field plot bearing is created along the transmit sector center bearing (Source Horizontal Steer) of the plan view display.
- The xy trace data corresponds to the depth indicated by the white bar in the full-field plot.
- The xy trace data, in the plan view display, is valid for the indicated sector on the plan view plot.

Changes in vertical transmit and receive parameters are often more distinct on the full-field display than on the plan view display. Horizontal transmit and receive characteristics are more evident on the plan view display; the full-field display essentially does not have a horizontal component to it. (Changes to the receive horizontal width will, however, affect the beam noise and beam reverb traces.)

Section Four

User Inputs

4.0 User Inputs

Tables 4-1 through 4-3 list the operator input parameters for environmental, ownship, target, and active sonar data. Additional information on each parameter is supplied following the appropriate table.

Table 4-1

Select Environmental Parameters

Select Environmental Parameters	Limits
Month	1-12
Own_Ship Latitude (+N, -S) (Example: 40.1 = 40 deg 6 min North)	-90 to 90
Own_Ship Longitude (+E, -W) (Example: -135.2 = 135 deg 12 min West)	-180 to 180
Maximum Range (nm)	5-500
Range Step (nm)	.25-2
Sea State (Sea State * 5 = Wind Speed)	0-8
Volume Scattering Strength (dB/SY) 1 = low, 2 = med, 3 = high, or user selected	-100 to 3
Volume Scattering Depth (ft) 1 = src/rcv depth, or user selected	0-3000
Bottom Loss Province (MGS) 1 = good reflector, 9 = poor reflector	1-9
Bottom Scattering Strength 1 = default, 2 = rock, 3 = silt, 4 = mud, or user selected	-100 to 4
Ambient Noise (Enter a value if source frequency below 500 Hz)	0-150

Table 4-2

Select Own-ship and Target Parameters

Select Own-ship and Target Parameters	Limits
Src/Rev Depth (ft)	0-3000
Own-Ship Speed (kts)	0-50
Own-Ship Course (˚T)	0-359
Target Depth (ft)	0-3000
Target Speed (kts)	0-50
Target Course (˚T)	0-359
Target Strength (dB) (not corrected for aspect)	0-50

Table 4-3

Select Active Sonar System Parameters

Select Active Sonar System Parameters	Limits
Frequency (Hz) (center of the band)	1-10,000
Pulse Length (sec)	.001-10
Bandwidth (Hz)	1-1000
Source Level (dB)	180-250
Side Lobe Level (dB) (transmit and receive side lobes; horiz and vert)	-10 to -50
Source Horizontal Steer (°T) (enter a factor of 5; also the full-field bearing)	0-359
Src Horizontal Width (enter a number evenly divisible by 10)	1-360
Rev Horizontal Width (degrees) (used for receive beams)	1-360
D/E (+ up, - down) (used for transmit beam and receiver beams)	-60 to 60
Src Vertical Width (degrees) (used for transmit beam)	1-180
Rev Vertical Width (degrees) (used for receive beams)	1-180
Detection Threshold (dB)	0-30

- **Month** is used to determine which sound velocity profiles will be extracted from the GDEM database.

- **Lat/Lon** is used to determine what data to extract from the sound velocity profile database (GDEM), the bathymetry database (DBDB5), and the Low Frequency Bottom Loss (LFBL) database. The HFBL database is not currently implemented. Location information should be entered in degree decimal-degree format.

- **Max Range**--the calculation will be performed and displayed from range 0 to the specified maximum range.

- **Range Step** determines how often a calculation will be performed.

- **Sea State** is converted to wind speed (SS*5 = wind speed) in knots which is used in the calculation of surface reverb (actually used in calculation of TL to the surface which is not displayed) and ambient noise.

- **Volume Scattering Strength** should be carefully chosen by the user because a database with this information has not been implemented. This input should be chosen based on location, frequency, and type of scatterer and should be a negative number in

dB per square yard (dB/SY). This value affects volume reverberation level(s). The less negative the number, the higher the volume reverberation.

- **Volume Scattering Depth** is the depth in feet at which the scattering layer is placed. The model assumes the scattering layer extends out to the maximum range for all azimuth angles. This value affects volume reverberation level(s).

- **Bottom Loss Province** is used when the input frequency is above 1000 Hz. This is a high frequency bottom loss province number.

- **Bottom Scattering Strength** affects the bottom reverberation calculation. The default value is - 27 dB/SY and should be used for all frequencies in water depths greater than 2000 ft. For comparison purposes, mud, silt, and rock areas can be represented by -33.5, -25.5, and -18.7, respectively. These values were actually obtained for shallow water areas at frequencies above 4 kHz. If the user can find better information for shallow water cases, this information should be used. For site specific runs, caution should be used to ensure that the chosen value reflects the actual bottom composition. The number should be a negative number in dB/SY.

- **Ambient Noise** is used if the transmit frequency is below 500 Hz. The user should enter the noise in dB in a 1 Hz band. The assumption is made that the noise is flat across the band. This input will be corrected for the receiver bandwidth and receiver beam dimensions (DI). If the transmit frequency is greater than 500 Hz, ambient noise is calculated as described in paragraph 4.4

- **Src/Rcv Depth** is used in the full-field and plan view calculation and specifies the depth of the transducer.

- **Target Depth** is used in the calculation of plan view data. In the full-field calculation, the target could be at any depth-range pair.

- **Own-Ship Speed, Own-Ship Course, Target Speed, and Target Course** are used in the doppler rejection calculation if the transmit waveform is narrow band. Paragraph 4.3.1 contains information about this calculation. Neither own-ship course nor target course are used to determine the full-field bearing.

- **Target Strength** is the random aspect target strength in dB.

- **Frequency** is the center frequency (fc) of the transducer in Hz.

- **Pulse Length** is the duration of the transmitted waveform in seconds. This input, along with the bandwidth, is used to determine if the waveform is a narrow band or a wide band signal.

- **Bandwidth** in Hz is the frequency range of the transmit and receive arrays centered on the frequency input. It is used, along with the pulse length, to determine if a waveform is a narrow band or a wide band signal. It is also used in the ambient noise calculation to determine the noise in the receiver band.

- **Source Level** in dB re. 1 μPa at 1 yd. This is the total power in the transmit band. If the bandwidth is modified, the source level must be modified. This parameter is also know as transmit level (transmit level = "source level" – transmit attenuation).

- **Side Lobe Level** in dB is used for the horizontal (REVERB/BEAMFORM) and vertical (ASERT) side lobe level for both the transmit beam pattern and the receive beam pattern. The side lobe level input is the number of dB down from the input SL value. Only used for the cylindrical beam pattern.

- **Source Horizontal Steer*** is the center of the transmit beam (sector center). This is also the bearing of the full-field calculation. Only used for the cylindrical beam pattern.

- **Src Horizontal Width*** is the width of the transmit beam and is centered on the source horizontal steer. Only used for the cylindrical beam pattern.

- **Rcv Horizontal Width** is the horizontal width of all receive beams. The number of receive beams is not an input; see paragraph 5.4.2 for further explanation.

- **D/E** is the depression/elevation angle in degrees. The transmit main beam and the receive beams will be pointing in this direction. A positive number points the main lobe up towards the surface. A negative number points the main lobe down towards the bottom. Only used for the cylindrical beam pattern.

- **Src Vertical Width** is the vertical width of the transmit beam centered on the D/E angle. Only used for cylindrical beam pattern.

- **Rcv Vertical Width** is the vertical width of the receive beams centered on the D/E angle.

- **Detection Threshold** is the SNR required for detection at some desired probability of detection and probability of false alarm.

*Because the model calculation is only performed for 72 radials (every 5 degrees), it was necessary to make the Source Horizontal Steer and the Src Horizontal Width evenly divisible by 5 degrees.

4.1 Comparison Matrix

Table 4-4 is a matrix that shows the relationship between each user input variable and the different available data types. A "D" in a column indicates that the variable is used directly in the calculation of the data type (or to extract database information). An "i" in a column indicates that the variable was used in a previous calculation, the result of which was used in the calculation of this term. For example, a change in frequency affects the TL calculation ("D"), which is also reflected in the echo calculation ("i").

Table 4-4

Matrix of Relationships Between User Input Variables and Displayed Data

Input Variable	TL	Echo	Beam Reverb bot	Beam Reverb sur	Beam Reverb vol	Beam Reverb tot	Beam Noise	SE
Month	D	i	i	i	i	i		i
Lat/Lon	D	i	i	i	i	i		i
Max Range								
Range Step								
Sea State				D		i	D	i
Vol Scat Strength					D	i		i
Volume Depth					D	i		i
Bottom Loss	D	i						i
Bottom Scat Strn			D			i		
AN							D	i
Src/Rcv Depth	D (ff)	i	i	i	i	i		i
OS Speed						D		i
OS Course						D		i
Target Depth	D (ff)	i	i	i	i	i		i
Target Speed						D		i
Target Course						D		i
Target Strength		D						i
Frequency	D	i		D	i	D	D	i
Pulse Length		D	D	D	D	i		i
Bandwidth		D				i	D	i
Source Level		D	D	D	D	i		i
Side Lobe	D (ff)	r (pv)	r	r	r	i		i
Src Hsteer		r (pv)	r	r	r	i		i
Src Hwidth		r (pv)	r	r	r	i		i
Receive Hwidth			D	D	D	D	D	i
D/E	D	i	D	D		i		i
Vertical Width	D	i	i	i	i	i	D	i
DT						D	D	D

D = value of variable applied, either directly in a formula or to index a depth or database.
i = applied in previous module; a change in a term (e.g., TL) of the equation of interest effects this change.
r = related to source level used.
(ff) = a more obvious or intuitive comparison can be made on this display; changes as a function of depth or vertical sonar system parameters.
(pv) = a more obvious or intuitive comparison can be made on this display; changes as a function of azimuth or horizontal sonar system parameters.

The table provides an indication of the possible comparisons that can be made. The user must ensure that the comparison is relevant and appropriate. The most straight forward comparison is one where only one variable of interest is changed. **The user must be careful when changing a number of variables. This is especially true when changing bandwidth, pulse length, TS,**

and DT. The interdependency of these variables is not automatically accounted for by the model. The user has the burden of changing these dependent variables as appropriate. For example, a change in pulse length will not affect the values for TS and DT. The user must enter the appropriate numbers here for the comparison to be accurate relative to some previously exercised run

4.2 Beam Patterns

An omni-directional beam pattern and a cylindrical beam pattern can be represented by the model. The user **will not** need to select the type of beam pattern from the user input display. Based on the information input by the user, the model will default to the appropriate beam pattern. Figure 4-1 shows the difference in performance resulting from an omni-directional beam pattern and a directional beam pattern.

4.2.1 Omni-Directional Beam Pattern

To generate a run for an omni-directional source and an omni directional receiver, the user should input the following:

SRC Horizontal Width	360
RCV Horizontal Width	360
SRC Vertical Width	180
RCV Vertical Width	180

Input of these values automatically sets the array flag (required by the model) to omni-directional. **The SRC Horizontal Steer, D/E, and Side Lobe Level are not considered for the omni-directional case.**

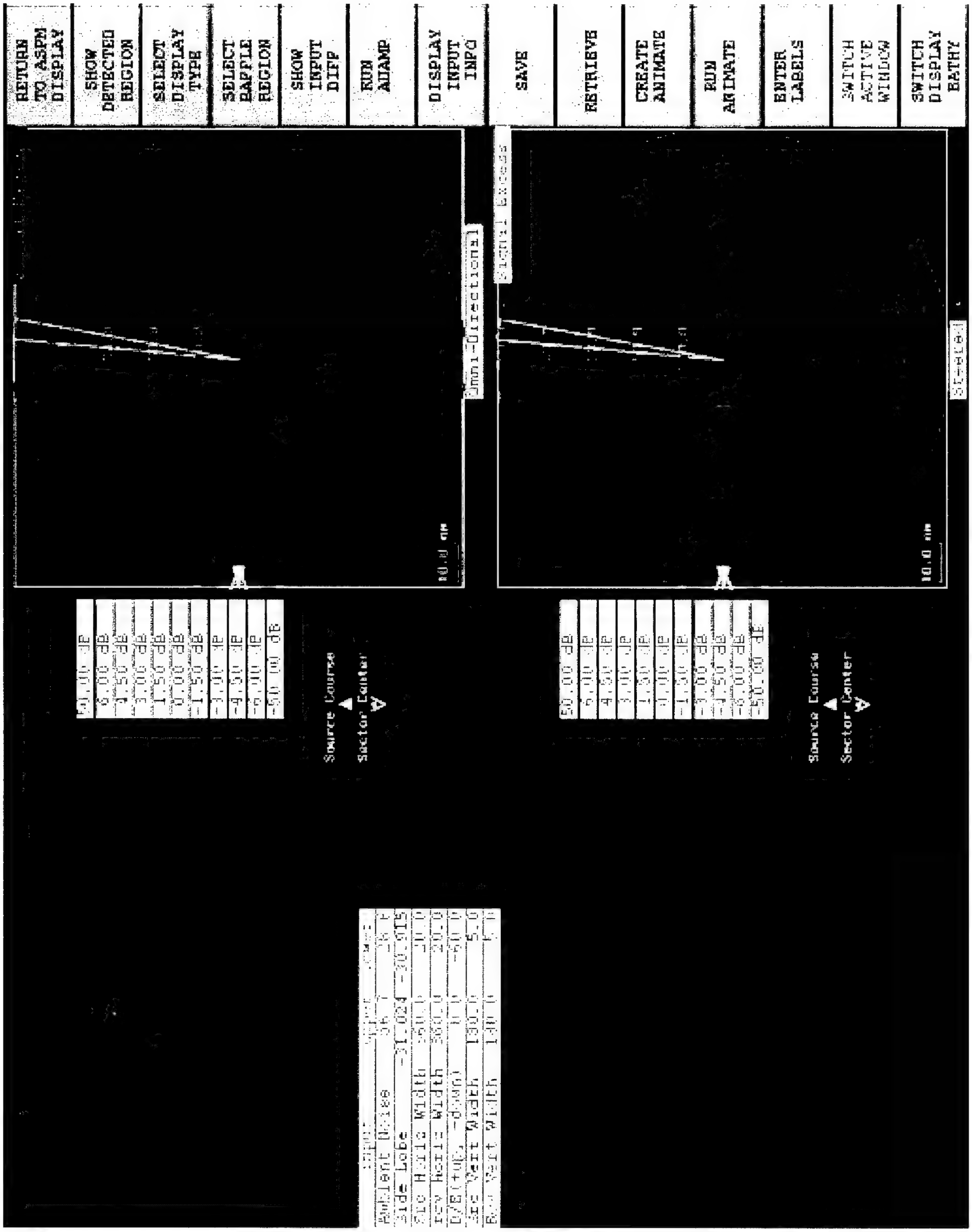


Figure 4-1. Beam patterns—Omni-directional vs. directional.

4.2.2 Cylindrical Beam Pattern

If the user does not input the values listed in paragraph 4.2.1, the array flag will automatically default to cylindrical. The cylindrical array is modeled as one steerable main lobe with one fixed side lobe level. Figure 4-2 shows a transmit beam pattern. Each receive beam will have a shape similar to this transmit beam, but will depend on the receive inputs provided. For each model run, the source (SRC) inputs will be used to specify one transmit beam and the receive (RCV) inputs will be used to specify multiple, identical beams.

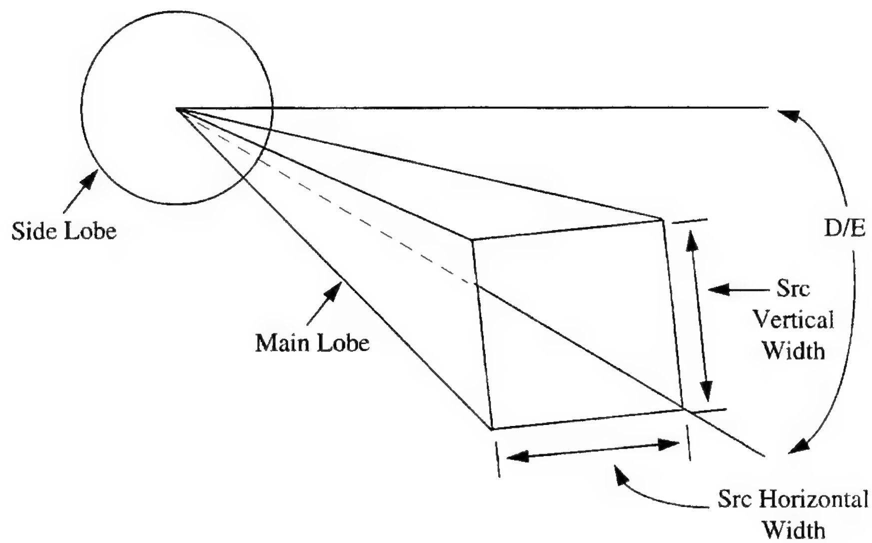


Figure 4-2. Cylindrical array representation—Transmit beam.

The main lobe is defined by the following variables:

SRC Horizontal Steer

SRC Horizontal Width

RCV Horizontal Width

D/E

SRC Vertical Width

RCV Vertical Width

The SRC Horizontal Steer input is referenced to true north **not** to ownship heading. The user must enter a SRC Horizontal Steer, which is evenly divisible by 5, and a SRC Horizontal Width, which is evenly divisible by 10. It is possible to modify the program to allow the user to enter any transmit horizontal steer direction and any size transmit horizontal width. This would, however, require that the model be run for every 1 degree (360 radials) and would result in much larger data files. Currently, the model calculation is performed every 5 degrees (72 radials).

The RCV Horizontal Width is the width of an individual receive beam.

The D/E parameter is slaved for the transmit and the receive beams. Both the SRC Vertical Width and the RCV Vertical Width are centered on the D/E parameter. A positive number indicates that the beam is steered up towards the surface. A negative number indicates that the beam is steered down towards the bottom.

Only one side lobe level (dB) input is presently available. This level is used for the transmit horizontal and vertical side lobe levels and the receive horizontal and vertical side lobe levels. Because only one side lobe level is used and the transition from the main lobe to the side lobe region is not gradual, the results will appear somewhat artificial on the plan view display. An actual beam pattern would not show such an abrupt transition. Figure 4-3 contains a diagram of the IMAT beam pattern compared with an actual beam pattern.

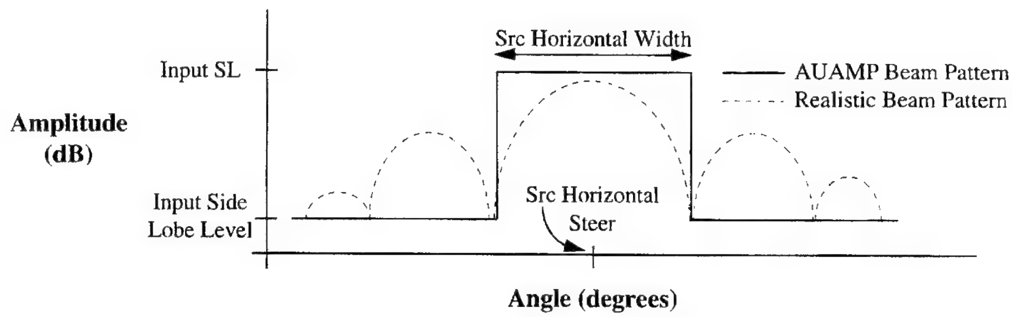


Figure 4-3. Transmit beam pattern comparison.

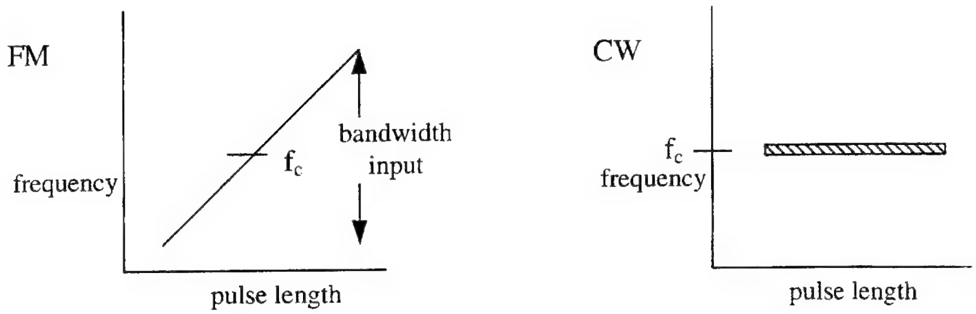
4.3 Waveforms/Wave Trains

As previously mentioned, the model calculation is performed for a single ping only. A single ping consists of a single waveform. In other words, a wave train cannot be defined.

The user can model the performance of a system transmitting either a CW or an FM waveform. The pulse length, bandwidth, and center frequency inputs (refer to) are used to define a waveform. Figure 4-4 is a visual representation of each waveform type. The user cannot make the distinction between different types of FMs (e.g., LFM, HFM) or between an up/down slide waveform.

To represent a CW waveform, the user should ensure that the product of the pulse length and the bandwidth (known as the time-bandwidth product) is equal to 1. When the time-bandwidth product is equal to 1, the signal is considered a narrow band signal. To represent an FM waveform, the product of the pulse length and the bandwidth should be greater than 1. When the time-bandwidth product is greater than 1, the signal is considered a wide band signal.

AUAMP uses information about the type of waveform (narrow band or wide band) to determine if doppler is a consideration and how a signal would be processed by a sonar system. This is discussed further in the paragraphs which follow.



Frequency (f_c)	1000 Hz
Pulse Length	1 sec
Bandwidth	10 Hz

Frequency (f_c)	1000 Hz
Pulse Length	.5 sec
Bandwidth	2 Hz

Figure 4-4. CW and FM waveforms.

4.3.1 Doppler Rejection Calculation

A doppler calculation is made only if the signal is a narrow band signal. The calculation uses own-ship speed, own-ship heading, target speed, and target heading inputs to determine the extent of the frequency shift of the echo return (equal to 2vf/c). The significance of this frequency shift is that the signal may be partially or entirely shifted out of the reverb frequency band. In an environment where reverb is the dominant noise source, this shift means that the signal has to compete against less interference, resulting in a higher SNR. The doppler rejection calculation uses the information about the frequency shift of the signal (doppler calculation) to adjust the reverberation levels.

The amount of reverberation rejection will vary from radial to radial in the plan view calculation. The reverberation rejection will be different for different radials because one of the factors involved in the radial velocity calculation (the line of bearing between the two units) changes.

4.3.2 Signal Processing

Information about the type of waveform is used to determine how the signal would be processed by a sonar system. A narrow band signal is processed by an energy detector and a wide band signal is processed by a matched filter. As a result of the matched filter processing of a wide band signal, a processing gain of 10 log (pulse length * bandwidth) is added to the echo level. The processing gain associated with a narrow band signal is 0.

4.3.3 Summary/Comparisons

The following summarizes the discussion of the previous paragraphs about waveforms.

CW	FM
pulse length * bandwidth = 1	pulse length * bandwidth > 1
narrow band	wide band
energy detector (no processing gain)	matched filter processing (processing gain)
doppler rejection calculation	no doppler rejection calculation

The following comparisons can be made:

- Long pulse length CW vs. short pulse length CW in a reverb-limited environment
- CW vs. FM
- CW for different own-ship and target speeds (i.e., range rate); CWs work best against high speed targets.

4.4 Ambient Noise Calculation

Figure 4-5 shows the method by which ambient noise is currently being calculated in IMAT. It assumes that the ambient noise level is the same for all directions. The ANDES noise model, which provides directional noise information, is not currently implemented in IMAT.

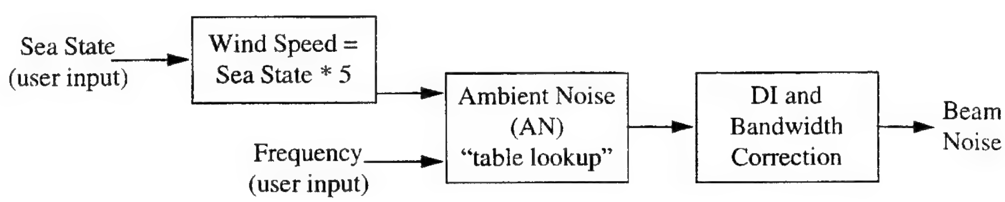


Figure 4-5. Calculation of ambient noise.

Frequency and wind speed (converted from sea state) input values are used to obtain an ambient noise level in a 1 Hz band. The ambient noise value is determined from an approximation to a figure containing deep-water ambient noise spectrum located in Urick's Principles of Underwater Sound. This value is then corrected for the bandwidth of the receiver and the receive beam dimensions (DI). The following equations are used by the model:

DI = 10 log (RCV Horizontal Beamwidth/360 - RCV Vertical Width/180).

Beam Noise + DT is actually displayed on the Echo/Noise/Reverb display. The beam noise value does not account for self noise.

Beam Noise = AN + 10log(bandwidth) - DI.

If the input frequency is below 500 Hz, the user must enter an ambient noise value. This value is then corrected for the bandwidth of the receiver and the receive beam dimensions.

Section Five

Specific Display Descriptions

5.0 Specific Display Descriptions

This section expands on the information provided in Table 4-4 . Each data type is discussed and a list of possible comparisons is provided.

5.1 One-Way/Two-Way Transmission Loss

Both one-way and two-way transmission loss data can be displayed. Many of the same concepts introduced in passive propagation can be demonstrated using the TL plot (e.g. ducting, cutoff frequency). Figure 5-1 is a comparison between one-way and two-way TL. Figure 5-2 contains an example of CZ propagation and bottom bounce propagation.

5.1.1 Transmission Loss Calculation

Transmission loss is calculated by the ASTRAL model. The sound velocity profile and bottom information are defined by the choice of location, range and bearing. The Gridded Digital Environmental Model (GDEM) database provides the necessary sound velocity profiles. DBDB5 or DBDBC provides the bottom bathymetry data. Either LFBL (aka BLUG) or HFBL (aka MGS) provides the required bottom loss information. LFBL is used for frequencies below 1000 Hz. HFBL is used for frequencies above 1500 Hz and is valid for frequencies between 1.5 - 4 kHz. Interpolation between LFBL and HFBL databases is performed within the model.

5.1.2 Comparisons

A change in any of the following variables will result in a change in the transmission loss:

- Month
- Location (Lat/Lon)
- Bottom Loss
- Source/Receiver Depth
- Target Depth
- Frequency
- Vertical Beam Pattern Characteristics
  - Side Lobe
  - D/E
  - Vertical Width

The month variable can be used to show how propagation conditions vary at one location throughout the year.

The latitude and longitude variables can be used to show different types of propagation conditions (ducting, CZ) in different locations. Propagation paths are more noticeable on the full-field display.

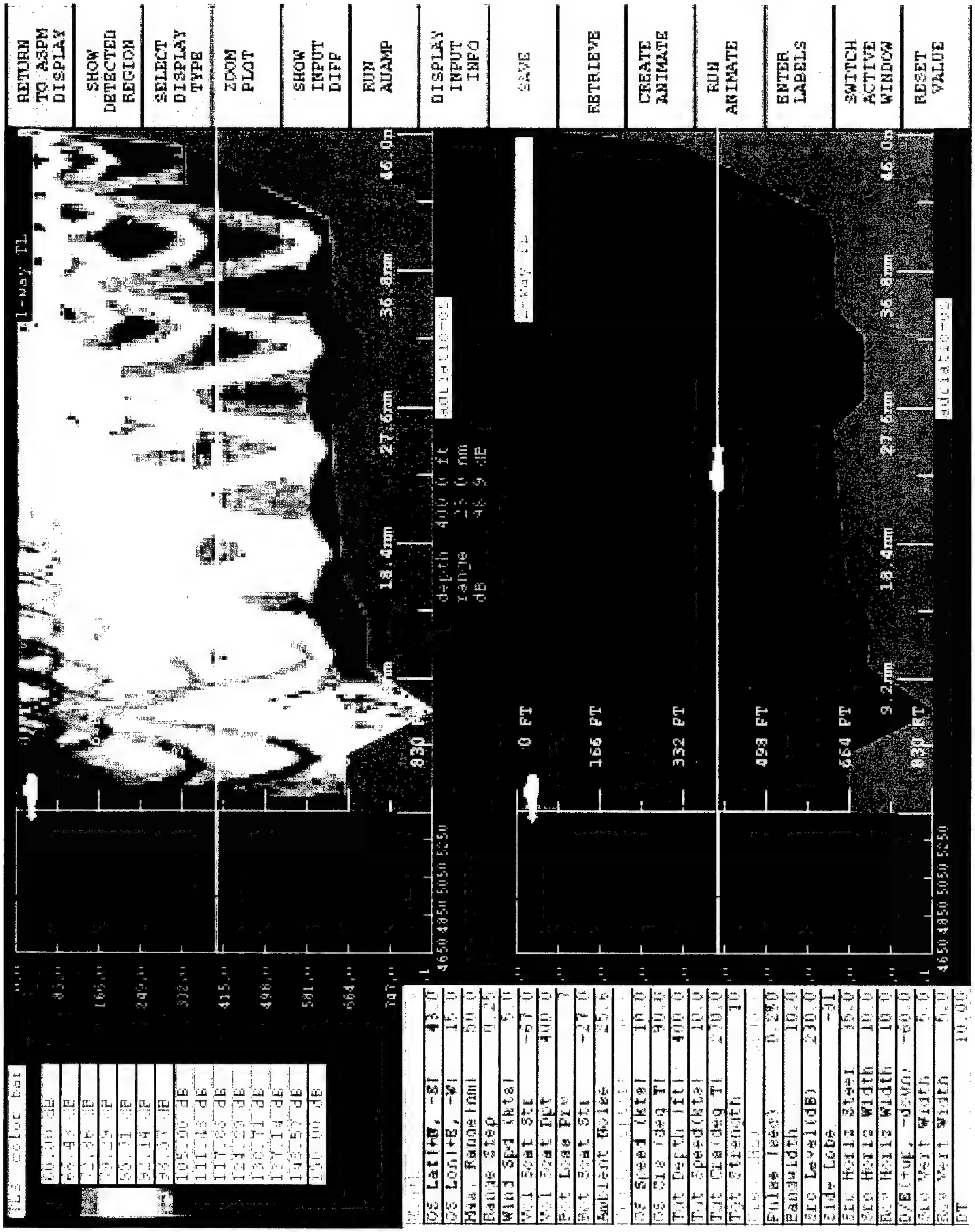


Figure 5-1. One-way TL vs. two-way TL.

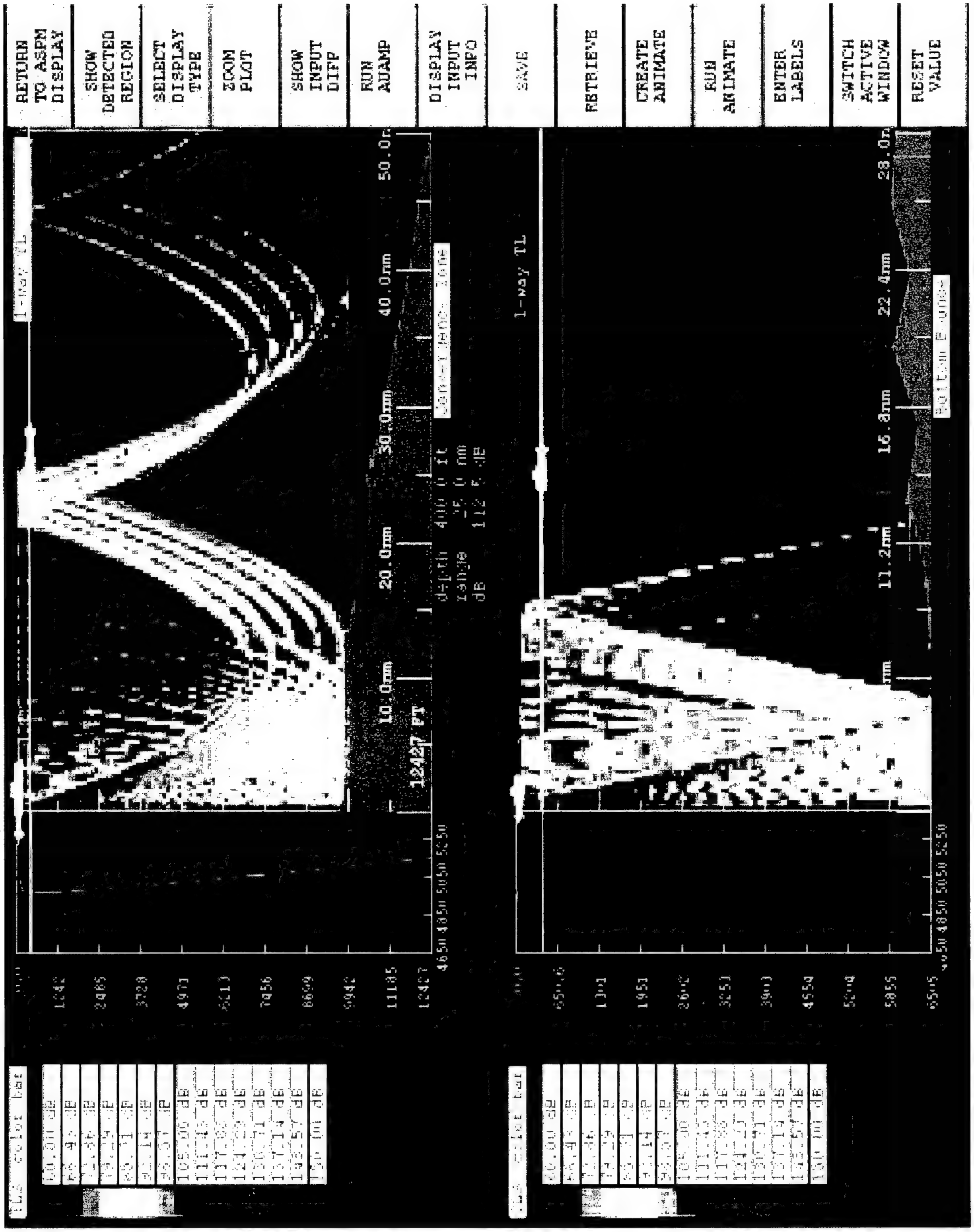


Figure 5-2. CZ and bottom bounce.

The MGS bottom loss variable can be used to make a comparison between different bottom "types." A value of 1 is a good reflecting bottom. A value of 9 is a poor reflecting bottom. A good reflecting bottom will result in less bottom loss and, therefore, less transmission loss. This is a somewhat artificial comparison since the bottom "type" for a particular location does not change; it is a fixed environmental parameter. A comparison of this sort can be made but should not be tied to a particular latitude/longitude. Also, bottom "type" is used somewhat loosely. An actual bottom "type" database does not exist; there is no database which ties bottom loss to bottom type. If the frequency is below 1000 Hz, the LFBL database and table are accessed to calculate the bottom loss information automatically. For higher frequency runs, the HFBL table is accessed. The HFBL database has not been implemented, and therefore the user must enter a province number appropriate to the latitude and longitude which was selected. Using the province number and grazing angle to the bottom (which is calculated by the model), the model determines the high frequency bottom loss in an area using the HFBL table.

The source/receiver depth and target depth variable(s) can be used to show changes to the dominant propagation paths as a function of geometry. The target depth variable is used for the plan view calculation.

The frequency variable can be changed to demonstrate higher transmission loss at higher frequencies.

Although the side lobe and vertical width parameters are considered in the transmission loss calculation, the SE display would be a more appropriate display to use when making comparisons of a change in either of these two variables.

A change in D/E will result in a change in the dominant propagation paths (e.g., introduction of bottom bounce paths).

A comparison between one-way TL and two-way TL can also be made.

5.2 Echo Plot

Figure 3-1, which was previously shown, contains a full-field echo level plot and the corresponding xy trace. The xy trace corresponds to the echo data for a target located at 338.9 feet.

5.2.1 Echo Level Calculation

Echo level is defined as follows:

$$\text{Echo} = \text{SL} - 2\text{TL} + \text{TS} + \text{PG}.$$

PG is the processing gain and is defined as 10 log (pulse length*bandwidth). For a description of processing gain refer to paragraph 4.3.2.

5.2.2 Comparisons

A change in any of the following variables will result in a change in the echo level:

- SL
- TS
- Pulse Length
- Bandwidth

Any change in two-way TL values will also affect the echo level values. Paragraph 5.1.2 lists the variables which will effect a change in transmission loss.

An increase in the SL will result in a corresponding increase in the echo level. When making such a comparison, the user must consider the effect an increase in SL will have on the total interference (i.e., noise-limited vs. reverberation-limited).

A change in TS can be used to compare targets with different characteristics; a comparison of a difference in size is one example. Lower TS values make the target more difficult to detect.

A change in TS can also be used to compare a target at different aspect angles (beam vice stern) to the source/receiver platform. **This comparison should only be made from the full-field plot.** It is inaccurate to think of the target strength input as aspect dependent on the plan view display; on that display the target strength number is for a random aspect target (this is technically also true for the full-field display but the full-field display format makes it easy to fake such a comparison). It is not necessary to change the target course to make this comparison. The user need only change the TS value. Target course information, along with target position information and ownship position information, is used to calculate any doppler rejection later on in the model if the signal was a narrow band signal. Target course information can also be changed if the user wishes to show a composite effect (aspect and doppler).

A change in echo level as a function of a change in pulse length is a more complex comparison to make. This is because a change in pulse length may result in a change in processing gain if the signal is a wide band signal and could result in a change in TS (which is not an automatic change).

For a wide band signal, a change in pulse length <u>will</u> affect the processing gain and <u>could</u> affect the TS value. The appropriate processing gain will be calculated automatically by the model. A change in the pulse length will not, however, result in an automatic correction to the TS input; the user must always enter the TS value appropriate to the pulse length. In a real world situation, the TS would increase with increasing pulse length up to some maximum pulse length, after which TS would no longer increase as the pulse length increased.

For a narrow band signal, processing gain is not a consideration (processing gain is zero by definition). Therefore, the only comparison that can be shown is an increase in echo level at a higher TS value as a result of a longer pulse length. To make this comparison, the user would need to change the TS value appropriately.

5.3 Reverb Components

5.3.1 Beam Reverb Components Equation

The following equation is used to model reverberation:

$$RL_{beam} = RL_{bottom} \oplus RL_{surface} \oplus RL_{volume} = \text{total beam reverberation}$$

$$RL_{type} = SL - 2TL + SS + 10 \log (\text{Area}) + 10 \log (\text{RCV Horizontal Width})$$

where type is bottom, surface or volume and SS is scattering strength.

Additional information about these equations is listed in Appendix B.

Reverberation is currently modeled for a single ping only. Reverberation will exhibit different characteristics depending on area propagation conditions and other environmental characteristics. Any change in the parameters that affect transmission loss (e.g., frequency, source depth) will be reflected in the reverberation levels. Total beam reverberation is the summation of the bottom, surface, and volume reverberation.

The scattering strength term (SS) is different for each type of reverberation. The bottom scattering strength term is a function of the Bottom Scattering Strength input and the grazing angle at the bottom. The surface scattering strength term is a function of the Wind Speed input, Source Frequency input, and the grazing angle at the surface. The grazing angle at the boundary changes as the D/E Angle input changes. A grazing angle of 90 degrees is perpendicular to the boundary.

The volume scattering strength term is a function of the Volume Scattering Strength and Volume Scattering Depth inputs. The volume scatterers are modeled as a thin layer at a single depth of interest. In other words, volume scattering is treated as surface scattering by a layer of volume scatterers.

5.3.2 Comparisons

A change in any of the following variables will result in a change in beam reverberation level:

- Bottom Backscattering Strength
- Sea State
- Frequency
- Volume Backscattering Strength
- Volume Scattering Depth (Diurnal Migration)
- Pulse Length
- Source Level
- D/E (and beam pattern as it relates to D/E)
- Doppler Rejection--wide band vs. narrow band signal
  - Pulse Length
  - Bandwidth

- Source Course and Speed
- Target Course and Speed

Bottom reverb will change when either the Bottom Backscattering Strength or the D/E Angle input is changed. The more negative the backscattering strength number, the lower the received bottom reverb levels will be. More bottom interaction, resulting from negative D/E angles, can increase bottom reverb levels.

Surface reverb will change when the Sea State, Frequency, or D/E Angle input(s) are changed. The higher the sea state, the higher the surface reverb. The higher the frequency, the higher the surface reverb. (A higher frequency and higher sea state also affect ambient noise levels.) More surface interaction, resulting from positive D/E angles, can increase surface reverb levels.

Volume reverb will change when the Volume Backscattering Strength or the Volume Scattering Depth input(s) are changed. The more negative the volume backscattering strength number, the lower the received volume reverb level. Through the proper choice of volume scattering depths, the effects of diurnal migration can be shown.

An increase in the pulse length will result in an increase in all of reverb component levels (bottom, surface, and volume). Reverb increases with increasing pulse length.

An increase in the SL will result in an increase in all of the reverb component levels. Reverb increases with increasing source level.

Doppler rejection does "affect" the reverb level but it is more accurate to discuss this feature in the context of signal excess.

5.3.3 Display Description

The Reverb Components plot contains one trace each for bottom, surface, and volume reverberation. The reverb components contribute to the total beam reverberation. Total beam reverberation can be shown by depressing the "T" key. The beam reverberation on this display is not corrected by the user input DT. **Therefore, the beam reverberation curve plotted on this display will be different from the beam reverb curve plotted on the Echo/Noise/Reverb (ENR) display by the value of DT.**

5.4 Signal Excess (SE)

5.4.1 SE Equation

The following is the SE equation:

$$SE = Echo - Total\ Interference - DT.$$

Any change that affects the echo level or the total interference level would also affect the value of SE. The DT variable has not been introduced prior to this calculation. A change in the

value of DT can only be noticed on a SE display. DT is a user input value. The DT variable should be used to represent the signal to noise ratio necessary for target detection for a chosen probability of detection and probability of false alarm scheme. Figure 5-3 is an example of a full field SE plot.

5.4.2 Plan View Format

The plan view SE plot is the most interesting plan view display type, but it is also the most difficult display to interpret. The cylindrical array transmit beam pattern is modeled as one main lobe and one side lobe of constant level. The user will input a source horizontal steer direction and a source horizontal width. The steer direction is referenced to true North. In other words, the transmit beam pattern has a user specified orientation, which can be seen on both the echo display and the SE display.

The user does not, however, specify an orientation for each receive beam. As a matter of fact, the user does not even enter the number of receive beams. The user only enters the horizontal width of a receive beam. The larger the width, the greater the value of the total interference. Consequently, the greater the total interference, the lower the signal excess. Although the total interference is not actually calculated for each line of bearing, it would be appropriate to think of this calculation as being performed for each bearing, where a receive beam of specified dimensions has its maximum response axis pointed along that line of bearing.

Using Figure 5-4, and reviewing the following questions and answers should clarify the description in the previous paragraph:

- Where is sector center? 090°T
  (user input--SRC Horizontal Steer, also identified by symbol)

- How wide is the sector? 120°
  (user input - SRC Horizontal Width)

- What is the source/receiver platform heading? 000°T
  (user input - Own-ship Course, also identified by ▲ symbol)

- How wide is each receive beam? 8°
  (user input - RCV Horizontal Width)

- How many receive beams are displayed? none
  (no user input)

- In what direction is each receive beam pointing? Assume MRA pointing along each line of bearing (no user input)

- Will I have positive signal excess for a target located along a bearing of 090°T, at a range of 35 nm, and a depth of 400 ft? In other words, how well will my system do in the given environment against a target at that range, bearing, depth with a specified TS (15 dB)? (No, that position is blue, which indicates a negative signal excess.)

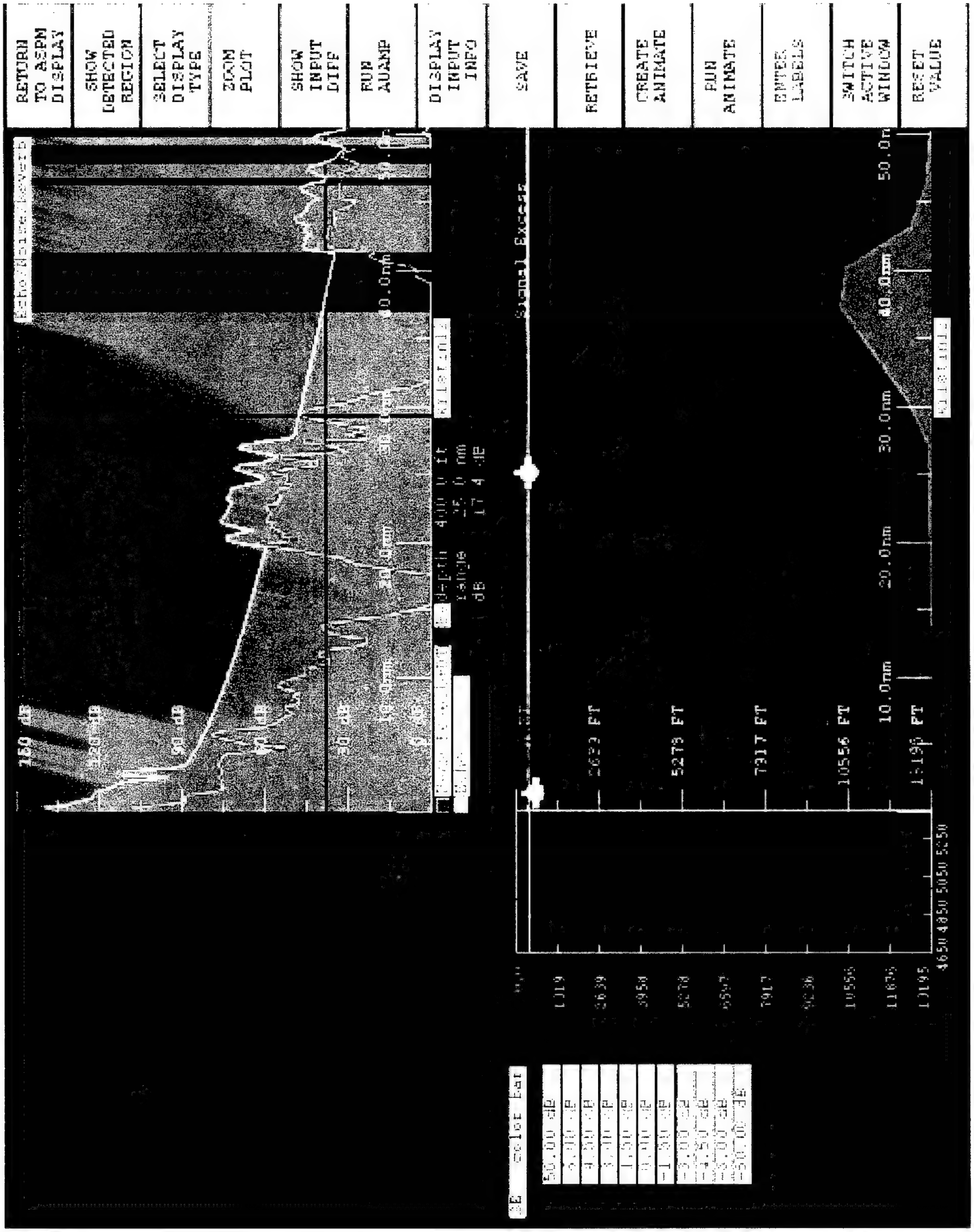


Figure 5-3. Full field signal excess.

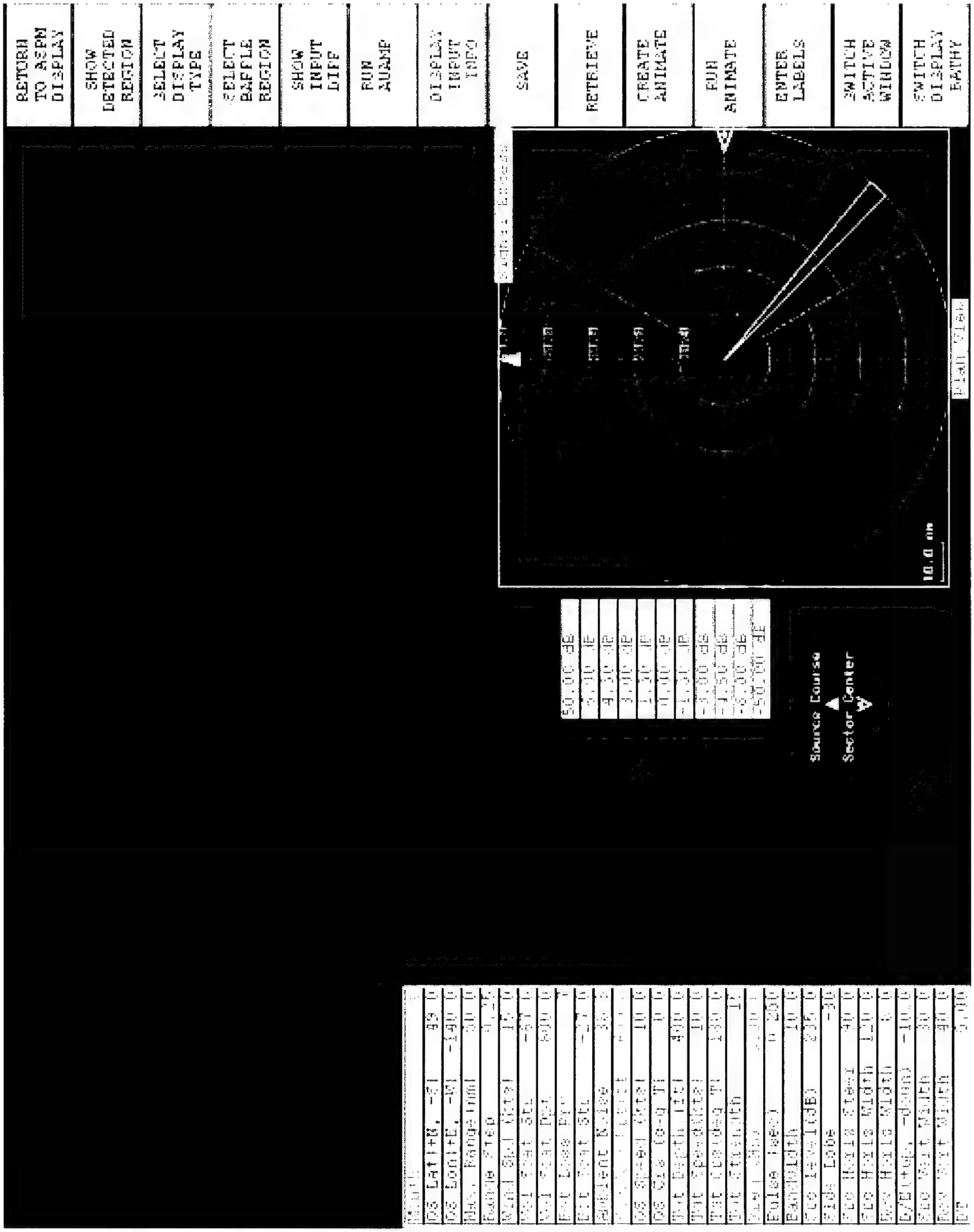


Figure 5-4. Plan view SE plot.

5.4.3 Comparisons

A change in any of the following variables will result in a change in SE:

- SL (in a noise limited environment).
- SL (in a reverb limited environment).
- Side Lobe Level.
- Receive Horizontal Beamwidth.
- Pulse Length.
- D/E (e.g. CZ annulus position).

Of course, a change in any of the input variables (except range and range step) would affect the SE calculation. For example, SE increases as the SL, TS, or DT increases. SE decreases as the total inference increases; the variables that affect reverberation and noise would determine the actual decrease. The changes to the variables listed above would provide the most interesting comparisons.

A change in source level affects both the echo level and the reverberation level equally. At ranges where the sensor is reverberation limited, an increase in SL will not significantly improve detection performance. At ranges where the sensor is noise limited, however, an increase in SL will improve detection performance.

Increasing the receive horizontal beamwidth will result in higher total interference levels and, thus, lower SE levels.

The user must be careful when creating a comparison between different pulse lengths. Under actual operating conditions, a change in pulse length affects reverberation levels, TS, and DT. Any change in the pulse length will automatically be reflected in the calculation of reverberation. The model will not, however, make any automatic changes to TS and DT as a function of a change in pulse length. The user must supply appropriate numbers. In summary, the user must ensure that appropriate values for TS and DT are input when wanting to demonstrate the impact of pulse length on SE. In addition, the user must consider the effect of a change in pulse length on doppler rejection or processing gain. In summary, in the real world as the pulse length increases the following occurs:

- Processing Gain Increases; Echo Level Increases (wide band).

- TS may increase if pulse length initially less than length required to simultaneously ensonify entire target.

- Reverberation will increase (reverb and echo increase by the same amount--10 log*pulse length).

- DT decreases.

5.5 Echo/Noise/Reverb

5.5.1 Equations

Each data type has been discussed in previous paragraphs. The echo level equation was discussed in paragraph 5.2. The beam noise equation was provided in paragraph 4.4. The beam reverb equation was defined in paragraph 5.3.

5.5.2 Comparisons

The user should consult the paragraphs listed above for a complete list of available comparisons.

A change in SL provides an interesting comparison. The ENR display shows the effect of a change in source level on both the echo curve and the reverb curve, demonstrating the interdependency of these two variables. The instructor can explain that while an increase in source level does increase the target echo level, it also increases the reverberation level. This will be of concern to the sonar operator in an environment where reverberation is the dominant source of interference.

The ENR display also shows the effect of changing source level at ranges where ambient noise is the dominant interference source. If beam noise is the dominant interference source, an increase in source level will widen the detection regions (positive signal excess). Beam Noise changes as a function of the following variables:

- Sea state (wind speed).
- Frequency.
- Receive horizontal beamwidth.
- Receive vertical width.
- Bandwidth.

An increase in any of the variables listed above will result in an increase in the beam noise level.

5.5.3 Display Description

This display type can be seen in both the full-field format and the tactical view format. Figure 5-5 is an example of this display type. It always displays echo level, beam reverberation, and beam noise. In the full-field format, this plot can only be displayed for the selected line of bearing (user input Source Horizontal Steer). In the tactical view format, this plot can be displayed for 72 different sectors.

The beam reverberation curve on this plot is beam reverberation + DT. The beam noise curve on this plot is beam noise + DT. It is necessary to correct these two curves by the DT value so that the echo curve can be visually compared against the dominant interference curve (noise or reverb) in an attempt to show the ranges at which positive SE exist. The SHOW DETECTED REGION key is a toggle key which will band the regions of positive signal excess.

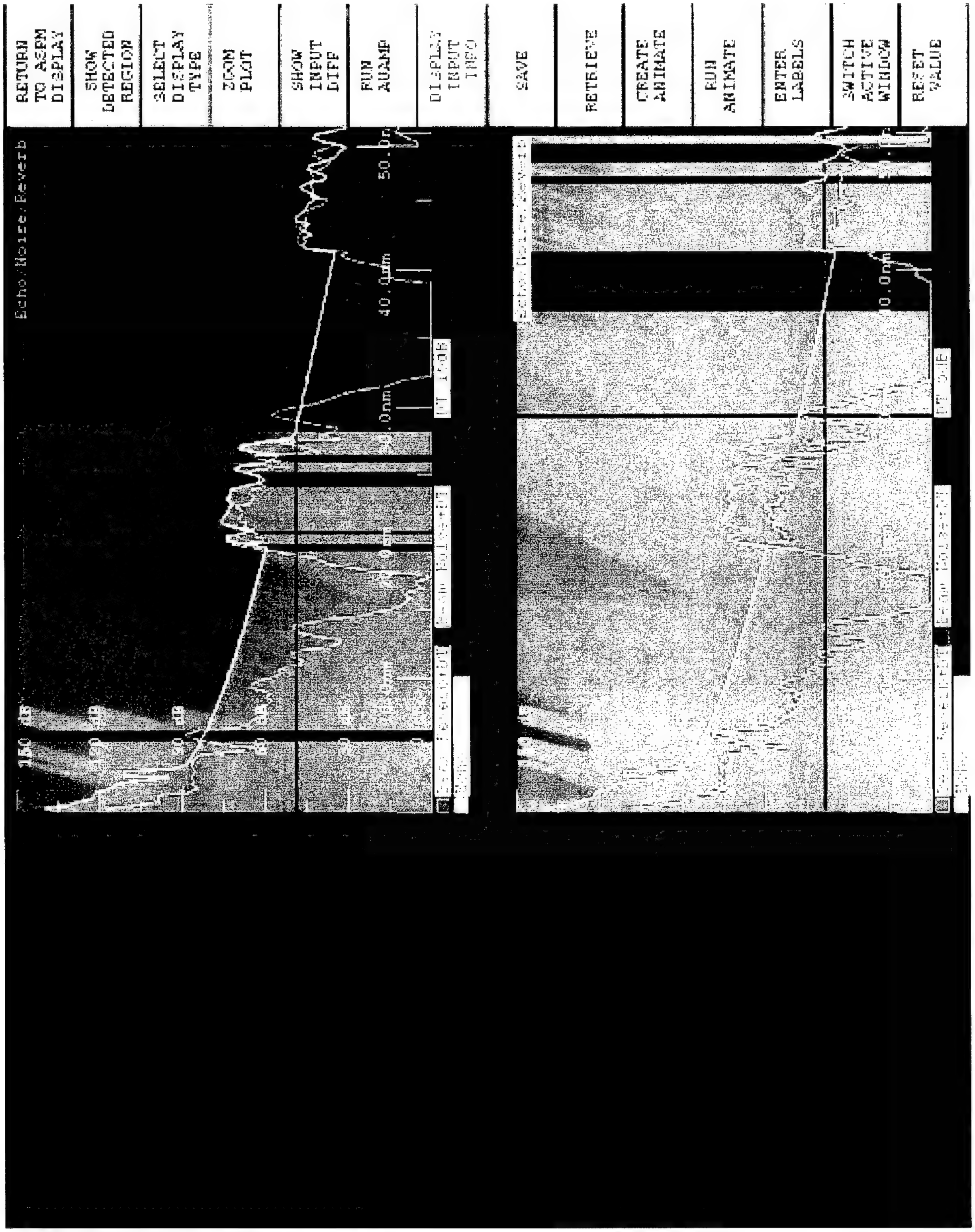


Figure 5-5. DT comparison.

Figure 5-5. DT comparison. As seen in the previous section, SE = Echo - Total Interference–DT. The total interference is defined as the power summation of the beam noise and the beam reverb. If DT is added to the beam noise and beam reverb curves on the echo/noise/reverb display, it is easy to determine the regions of positive SE because it corresponds to the ranges where the echo level is above the total interference + DT level. Because a total interference trace is not actually displayed, the visual comparison is not exact. To allow for a more exact visual comparison, the total interference curve would have to be plotted. The target echo return actually competes against the total interference level measured on a beam. If the noise curve and reverb curve are close in value, the total interference curve would be almost 3 dB higher than the curve with the higher levels.

Section Six

Menu Bar

6.0 Menu Bar

The information in this section describes the function of each key on the menu bars for the Full Field, Tactical View, and Miscellaneous displays.

6.1 Full-Field Display

Show Detected Region

This toggle key highlights regions of positive signal excess on the Echo/Noise/Reverb display. The display must be the active window, which can be selected by choosing the SWITCH ACTIVE WINDOW key.

Select Display Type

This key allows the user to select the display area (i.e. upper or lower) and the type of data to be displayed (e.g. one-way TL).

Zoom Plot

This key allows the user to zoom in depth and/or range.

Show Input Diff

This toggle key shows the difference between the inputs to the upper display and the lower display.

Run AUAMP

Depress this key to execute a single model run or multiple model runs (used for animations).

Display Input Info

Depress this key to show the input values entered for a model run. Input values are shown for the active window.

Save

Use this key to save data files or current settings file. A current settings file saves the data as it is currently displayed on the screen (e.g., data files, types, and labels).

Retrieve

Use this key to retrieve a data file or current settings file.

Create Animate

This key allows the user to specify the data file, display layout (upper, lower, both), data type, and time step for an animation. The user should set up the display as if it were to be saved as a current settings file. The user must have selected RUN AUAMP--multiple runs--before selecting this option.

Run Animate

This key is used to run an animate previously generated using the CREATE ANIMATE key. A step option is also available. Using this option, the instructor depresses the mouse key to continue through each frame in the animation.

Enter Labels

Each display label is initially set to a default and will be set to the file name after the file has been saved as a data set (SAVE - data). This option allows the user to change the label associated with each display area.

Switch Active Window

This toggle switch designates the active window.

Reset Value

This selection resets a zoomed display to the maximum depth and/or maximum range in the data file.

6.2 Tactical View Display

The plan view display keys have the same functionality as the full-field display keys described above. The ZOOM PLOT and RESET VALUE keys are replaced by the two additional keys described below.

Select Baffle Region

This key allows the user to eliminate data in a user defined baffle region, replacing it with black. The user must specify the extent in degrees of the region and this region will be automatically centered on the reciprocal of the own-ship's course.

Switch Display Bathy

This key will allow the bathymetry pictures on the display to be removed / displayed.

6.3 Miscellaneous

Depress T on the keyboard to display total beam reverberation on the reverb components display. This is a toggle key.

Section Seven

References

7.0 References

Urick, U. J., (1975). *Principles of Underwater Sound,* 2nd ed., New York: McGraw-Hill.

Acoustic System Performance Model (ASPM) 4.0A: User's Guide, 14 January 1994, SAIC, McLean, VA 22102.

Software Requirements Specification for ASPM, the Active Acoustic System Performance Model, May 1992, SAIC, McLean, VA 22102.

Appendix A

Active Demonstration Using IMAT

Active Demonstration using IMAT

Summary

The properties that govern active sonar employment are similar to those impacting passive performance, only more complex. The basic premise that forms the foundation of ASW remains the same. The goal is to always employ the source/receiver platform to optimize performance in an actual complex ocean, considering all factors, against an intelligent mobile target who will try to deny detection opportunity. A summary of the variables germane to operations follows.

The source is now an intentional emission from own ship vice an unintentional emission from a target (passive case). The pulse length, pulse type, power level, range scale, transmission Depression/Elevation (DE) angle, sensor operating depth, and speed are all variables the sensor operator must consider to optimize performance. The receiver may be either co-located or a third party platform.

In addition to background noise (seastate, shipping level, ocean turbulence, and self noise) active sonar performance may be critically impacted by reverberation (surface, volume, and bottom). Transmission loss is two-way vice the one-way in the passive case.

As in passive, the target position, both in the vertical water column and aspect to own ship, has significant impact. Additionally, the size, construction, and dampening characteristics of the target affect detectability.

The focus of the active demonstration is to use the capabilities of the IMAT system to visualize the complex interaction of these variables using representative sensor, modeled environmental and target characteristics.

The scope of this demonstration encompasses a review of the active sonar equation and a discussion of a representative sampling of the factors affecting performance. It is not intended to be a full treatment of active sonar parameters, but rather a representation of ordered concepts. Additionally, the many animation opportunities available in the IMAT architecture are not included.

Table A-1 lists the file names associated with each of the figures discussed below.

Table A-1

Figure Filename Listing

Figure	Figure Name	Filename
A-1	Signal Excess Plot	AA1_DEMO_SE
A-2	One-Way Transmission Loss	AA2_DEMO_MF_TL
A-3	Two-Way Transmission Loss	AA3_DEMO_MF_2TL
A-4	Echo Plot	AA4_DEMO_MF_ECHO
A-5	Echo/Noise/Reverb and Reverb Components	AA5_DEMO_ENR_RVB
A-6	Echo/Noise/Reverb and Signal Excess	AA6_DEMO_ENR_SE
A-7	Seasonal Signal Excess Plots	AA7_DEMO_BERMUDA_SEASONAL
A-8	Seastate Signal Excess Plots	AA8_DEMO_BERMUDA_SEASTATE
A-9	Echo/Noise/Reverb	AA9_DEMO_AREA_COMP
A-10	Plan View	AA7_DEMO_BERMUDA_SEASONAL

Full Field Demonstration

Note. Refer to Figure A-1. Signal excess plot.

From a "big picture" perspective, the overall Signal Excess plot shows the result of the manipulation of all variables for source/receiver, environment and the target ship.

A sample medium frequency (MF) active system is modeled for this example. The area is in the Atlantic Ocean near Bermuda. The lighter areas on both displays represent > 0 signal excess for a 50 percent probability of detection, given sensor line-up, source/receiver and target combination. The example shows long ranges in the shallow sound channel and convergence zone at about 35-45 nm. Notice that outside of the sound channel detections are limited to convergence zone. (See the zoom of the upper 3000 ft of the water column, lower display.)

The horizontal white line indicates target depth. The Submarine icon is used to show aspect. The range at which the icon appears is not significant.

As we have previously described, many factors affect active performance. Let's explore some of the variables and the IMAT Displays that are used to describe them.

Note. Refer to Figure A-2. One-way transmission loss.

This plot is the same as the passive example except that we are dealing with a pulsed transient source. Notice in the zoom (lower display) that the prevalent ducting is evident from a depth of 300 to 700 ft, and note the bottom bounce at 18-20 nm and CZ at 25-45 nm. The colors are scaled at approximately 6 dB steps, from 60-150 dB.

Remember that in active sonar we are primarily concerned with transmission loss from the source to target and back to the receiver. Because our receiver is co-located with the source, this will be 2x Transmission Loss (2TL).

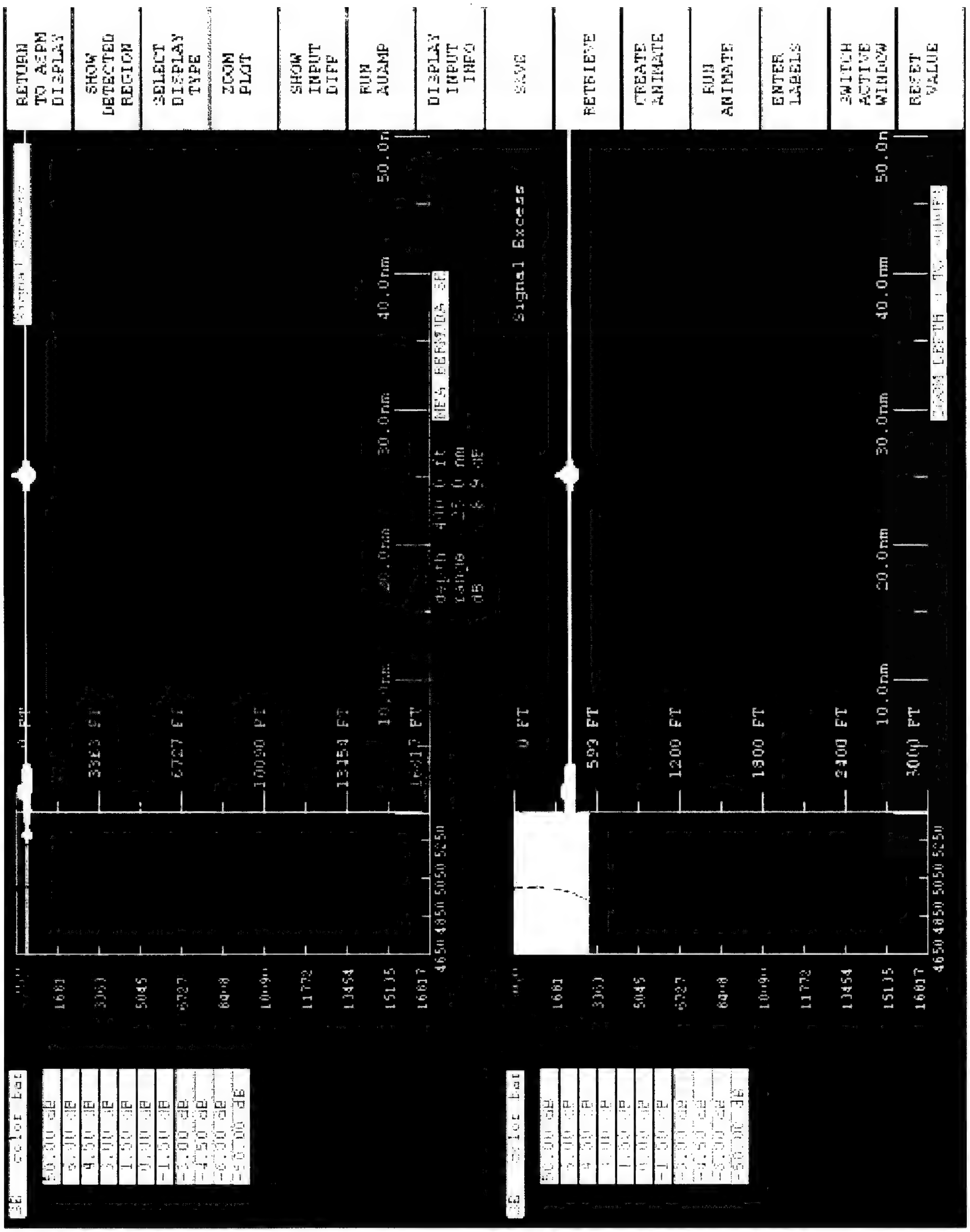


Figure A-1. Signal excess plot.

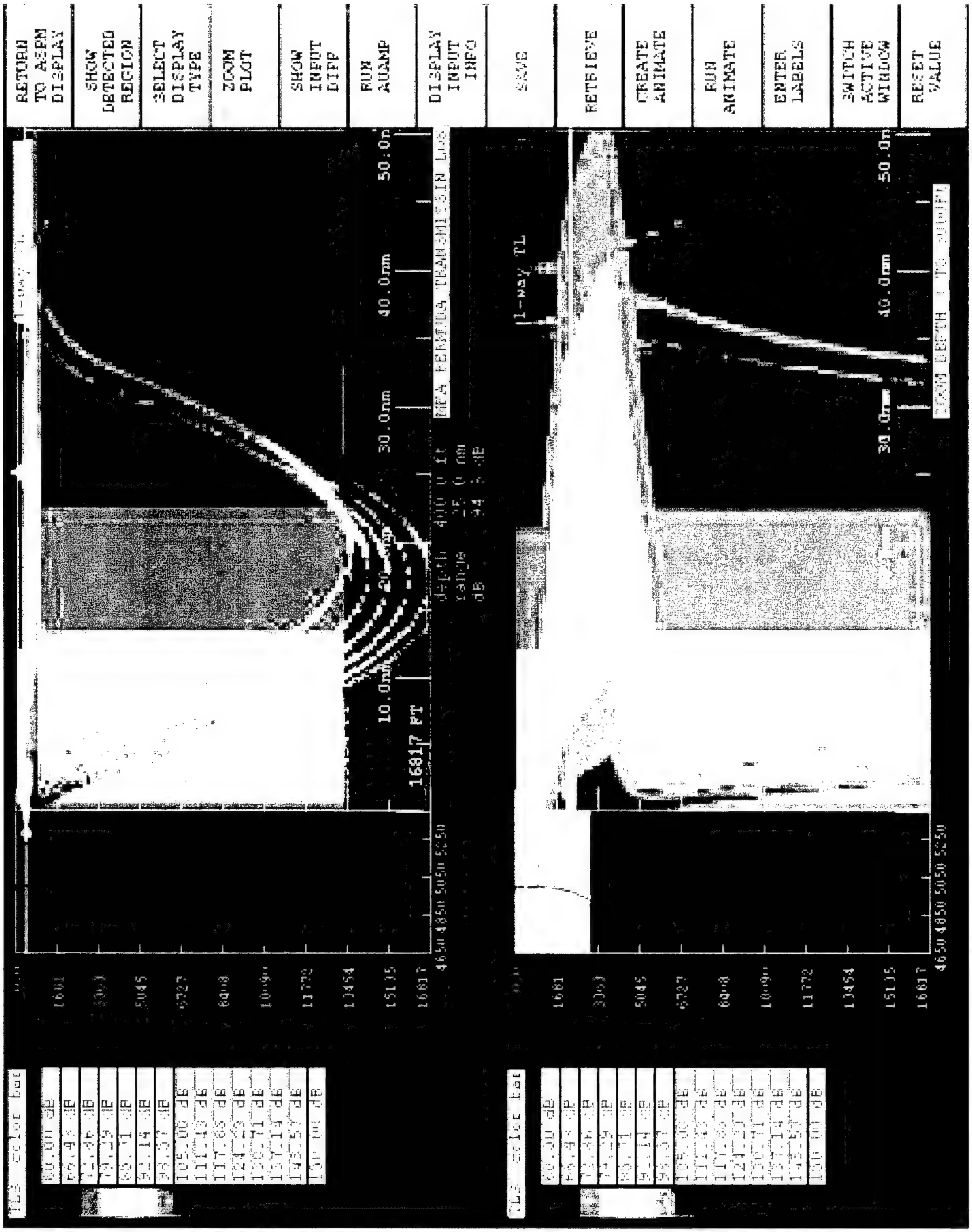


Figure A-2. One-way transmission loss.

Note. Refer to Figure A-3. Two-way transmission loss.

Two-way transmission loss is the transmission loss from the source to the target and back to the receiver. In a monostatic system we can assume reciprocity. The upper display shows 2TL in the Bermuda area for the source/target combination shown. The paths that appear to be available are DP (sound channel), BB and CZ. The zoom on the lower display highlights the apparent intensity of the duct.

In active sonar, we must consider the reflectivity of the target as well as transmission loss. This is called Target Strength (TS), and will vary as a function of target aspect, target size, reflective components and appendages. This can be illustrated in IMAT by the use of the Echo Plot.

Note. Refer to Figure A-4. Echo plot.

The Echo plot shows the echo level (SL-2TL+TS) and a processor gain for wide band pulses as a function of range and depth for a given source/target combination. By vertical movement of the target cursor (upper display) we can display echo level at receiver depth in a slice (lower display). The value of echo level illustrates this relationship: Echo level = Source Level (SL) - 2-way Transmission Loss (2TL) + Target Strength (TS) + Processor Gain (PG) (PG = 10 * Log (Pulse length * Bandwidth)). This is the level that would be available at the receiver if noise and reverberations were not present.

Interference level is the value of total interference with the transmitted signal due to the combination of background noise and reverberation detected at the receiver. At various ranges one or both of these factors may predominate.

Reverberation is primarily driven by seastate, bottom type, topographic complexity, depth, ship's position in the water column, and suspended scattering elements. Noise is driven by distant shipping, wind speed, self noise, and miscellaneous ambient interferers.

The resultant Echo level - Total Interference (noise + reverberation) = Signal excess (zero at the 50% probability of detection range).

Note. Refer to Figure A-5. Echo/noise/reverb and reverb components.

Total Beam Reverberation can be best understood by looking at the component parts: Surface, Bottom and Volume. Depending on the environment, any or all of these components will contribute to total reverberation. The upper display shows the total beam Reverb compared to noise and echo level. The lower display shows the effect of the three components as a function of range. Selecting the "t" key on the keyboard will display the total beam Reverb.

Notice that the levels of beam Reverb in the components display are not the same as in the EN plot. This is due to the addition of detection threshold (DT) to noise and Reverb levels in the EN plot.

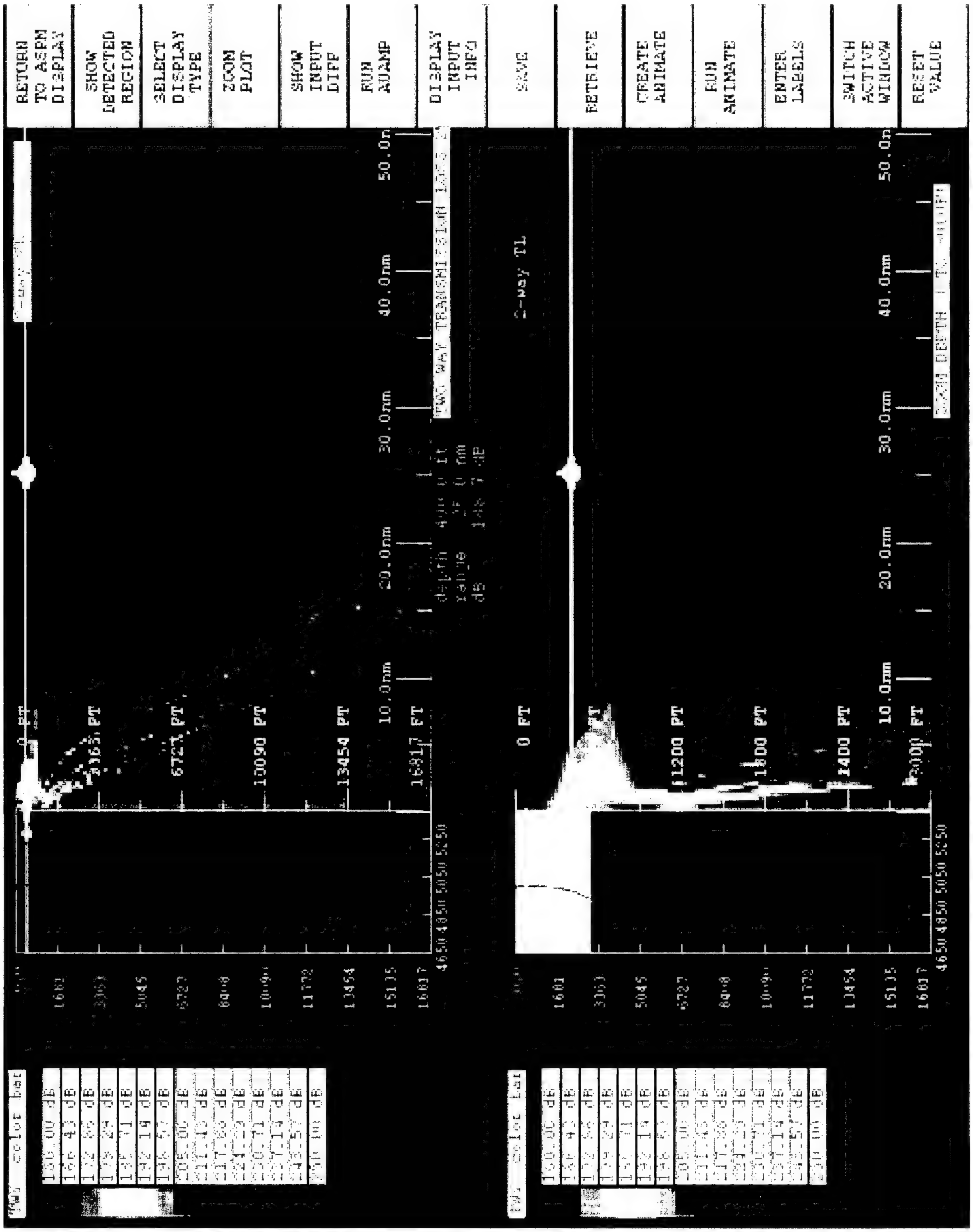


Figure A-3. Two-way transmission loss.

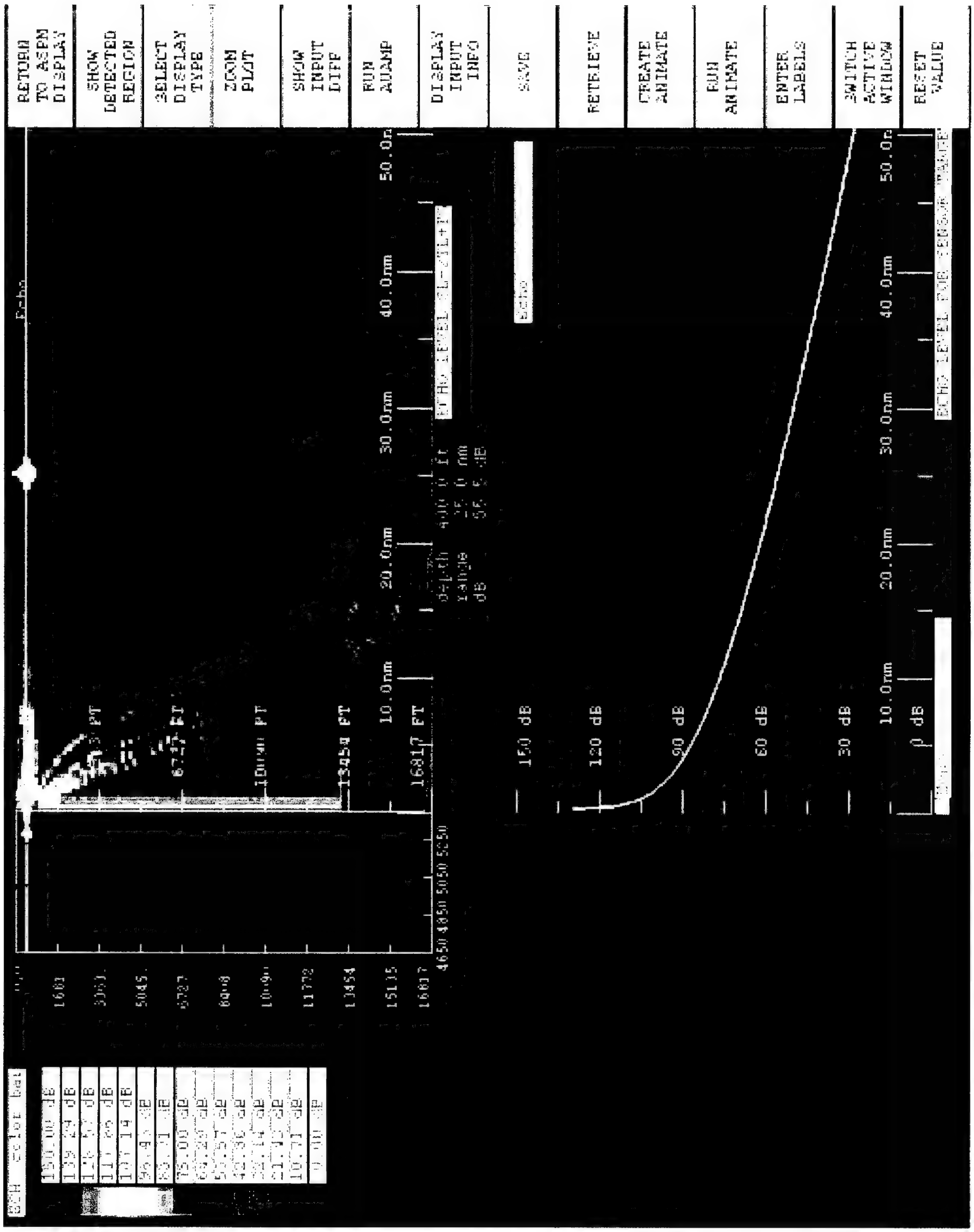


Figure A-4. Echo plot.

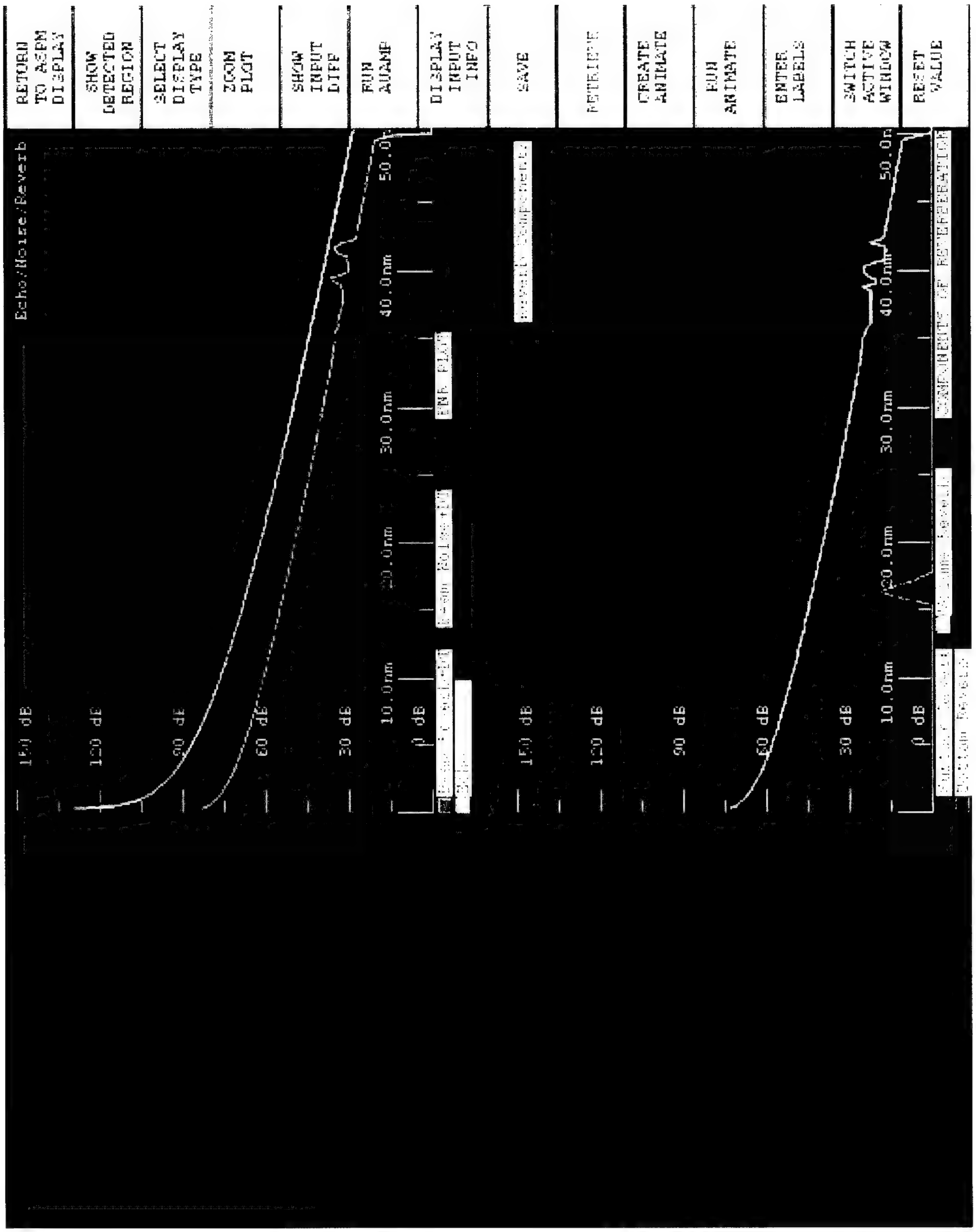


Figure A-5. Echo/noise/reverb and reverb components.

Note. Refer to Figure A-6. Echo/noise/reverb and signal excess.

In a perfect environment we would be nearing the end of the summary. However, just as in the passive case where we had the environmental interference (NOISE) limiting our ability to detect a signal, we also must consider noise and reverberation in the active analysis as "total interference," which limits our ability to detect an active return. The upper display is an Echo/Noise/Reverberation (ENR) plot, which shows the echo, beam background noise, and beam reverberation level as a function of range at a specific target depth.

Wherever the the upper line in the top display exceeds the beam noise and/or beam Reverb, we have signal excess with resulting detection. If the higher interference level limiting detection is noise, we are operating in a noise limited environment. Conversely, if the higher interference is reverberation, we are operating in a reverberation limited environment.

The signal excess display (lower display) shows the overall detection picture for our input parameters. With the submarine to the left can be positioned up or down in depth. This will change the ENR plot (upper) to show the echo, noise, and reverberation relationship at the new source/receiver depth combination.

We have completed a review of the various components of the active sonar equation through showing examples of a typical MF sonar in a given equipment lineup, with a sample environment, against a specific threat. However, each component of the basic "Triangle of Concern" that IMAT addresses has its own set of variables, each having dramatic effect upon the successful mission accomplishment.

Let's take a look at some of these variables. First, some examples of the variations in performance due to environment:

Note. Refer to Figure A-7. Seasonal signal excess plots.

This is an echo plot of our MFA system in Bermuda areas during different seasons. The plots are Depth zooms of the upper 3000 ft in the water column. The upper display is for July; the lower for February. In February a strong duct is evident centered at approximately 400 ft and CZ at ranges of 40 nm. By the summer season, the duct is eliminated as a result of near-surface warming. Weak convergence near the surface is the only exploitable path.

Note. Refer to Figure A-8. Seastate signal excess plots.

The upper display shows detection performance in smooth seas. The target would be detectable in the duct or at convergence zone ranges. A storm begins in the area causing choppy seas and the convergence zone is no longer present. The only long range available is if the target cooperates and remains in the duct.

Note. Refer to Figure A-9. Echo/noise/reverb.

The upper display shows an MF sonar system performance in a deep ocean area near Guam. Notice the severe refraction and the very narrow sound channel. Ranges would be less than 2 nm. In the lower display we show the same MF active system operating in the littoral areas of the Sea of Japan. The isovelocity condition and flat bottom yield reasonable performance even though the water is shallow.

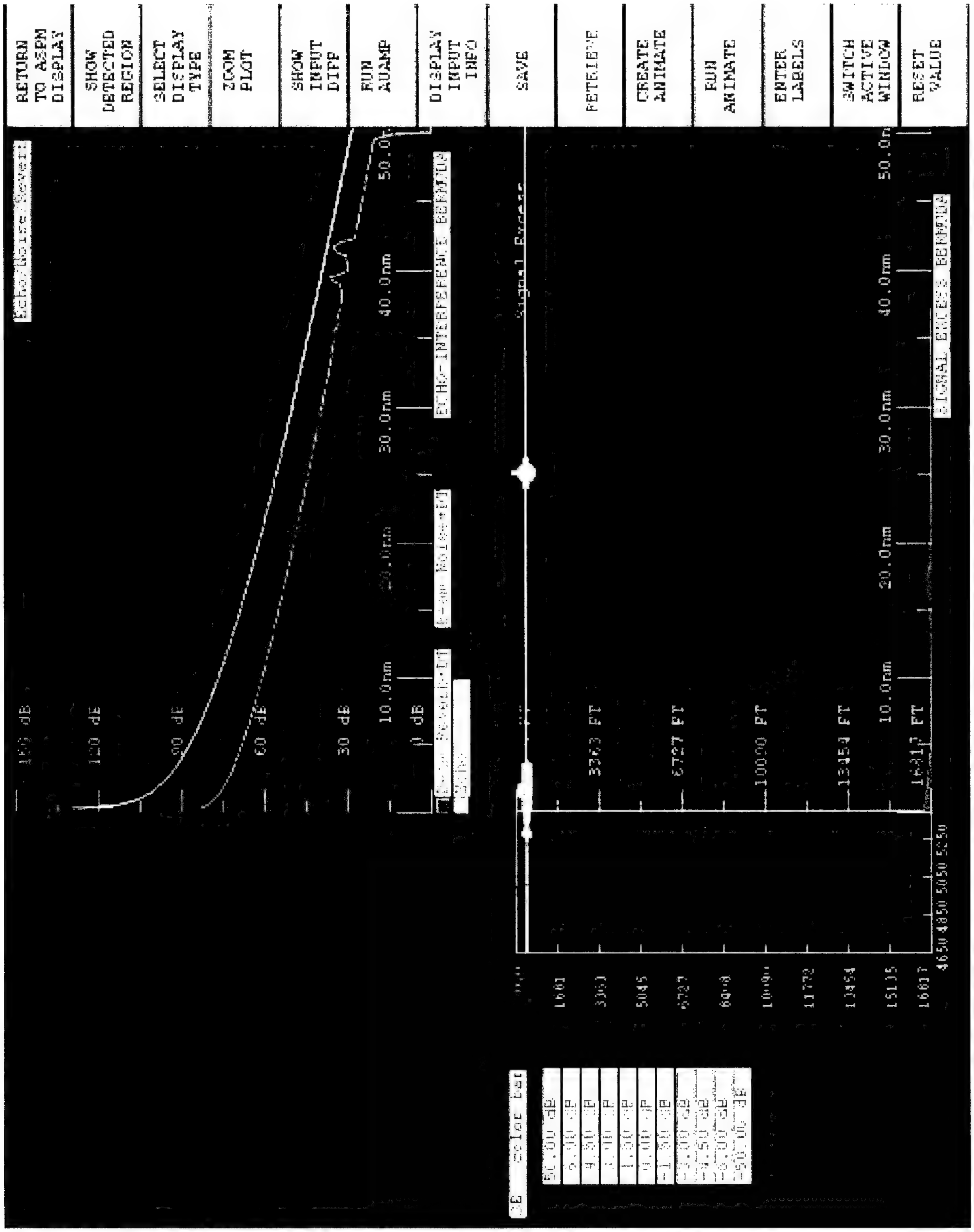


Figure A-6. Echo/noise/reverb and signal excess.

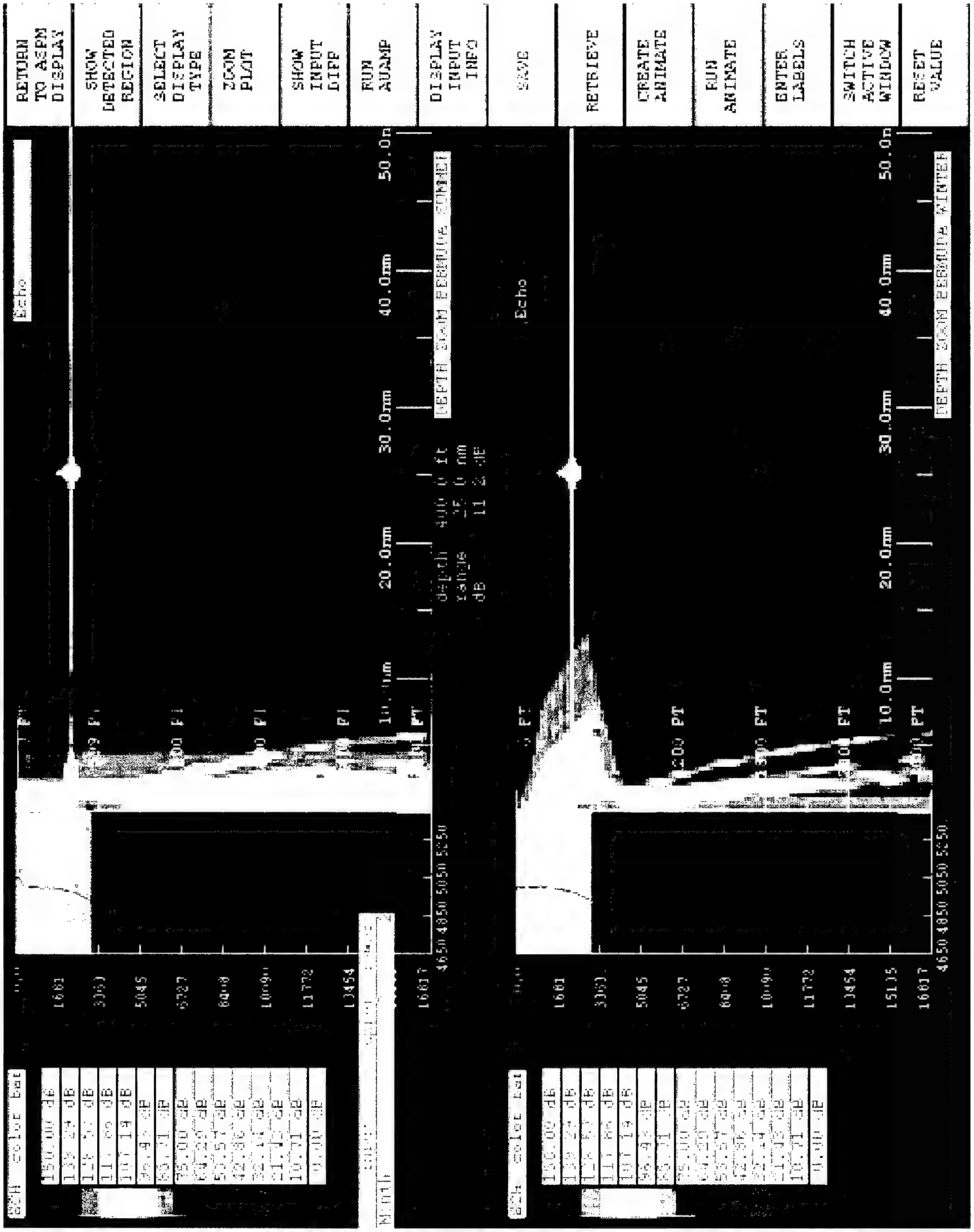


Figure A-7. Seasonal signal excess plots.

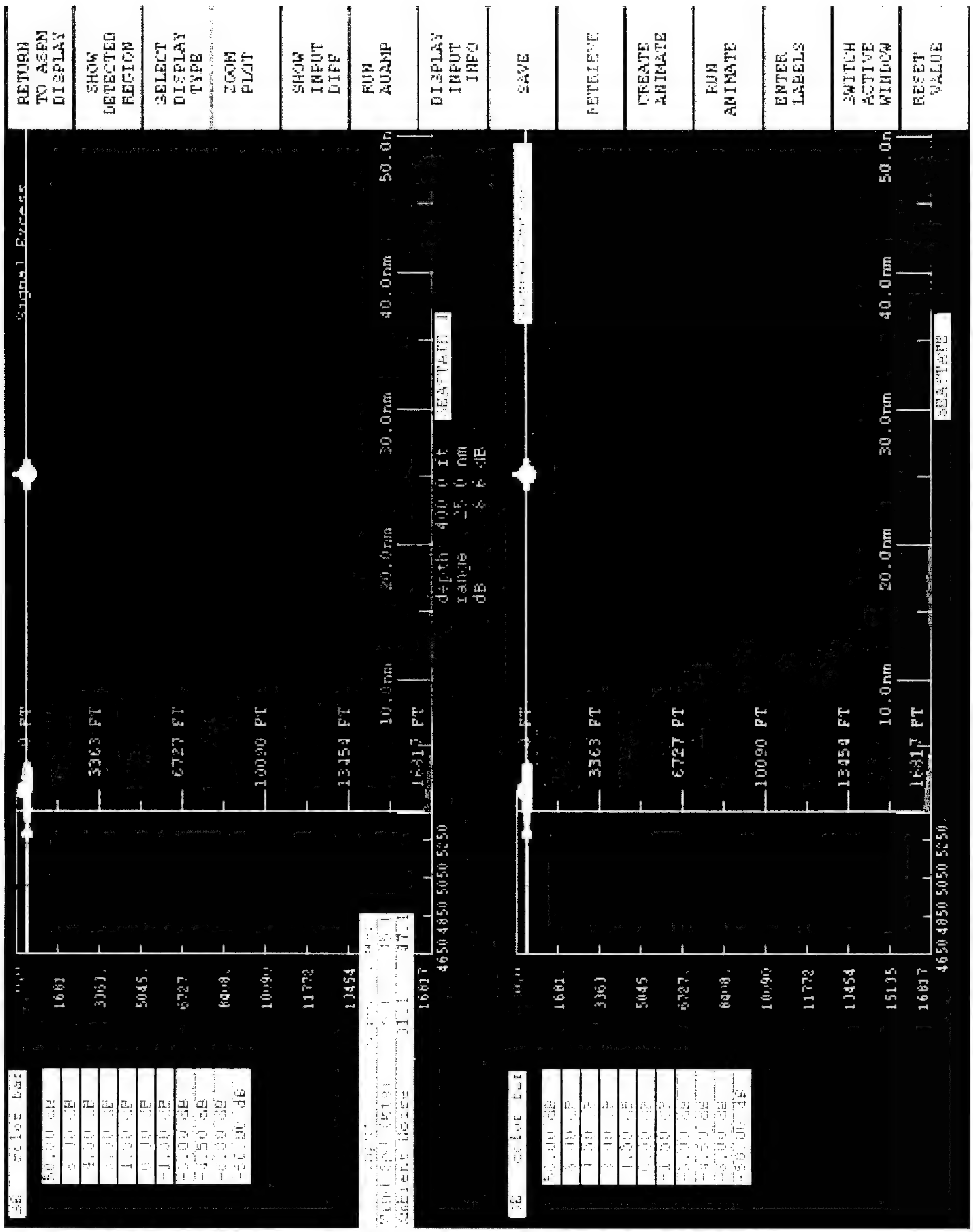


Figure A-8. Seastate signal excess plots.

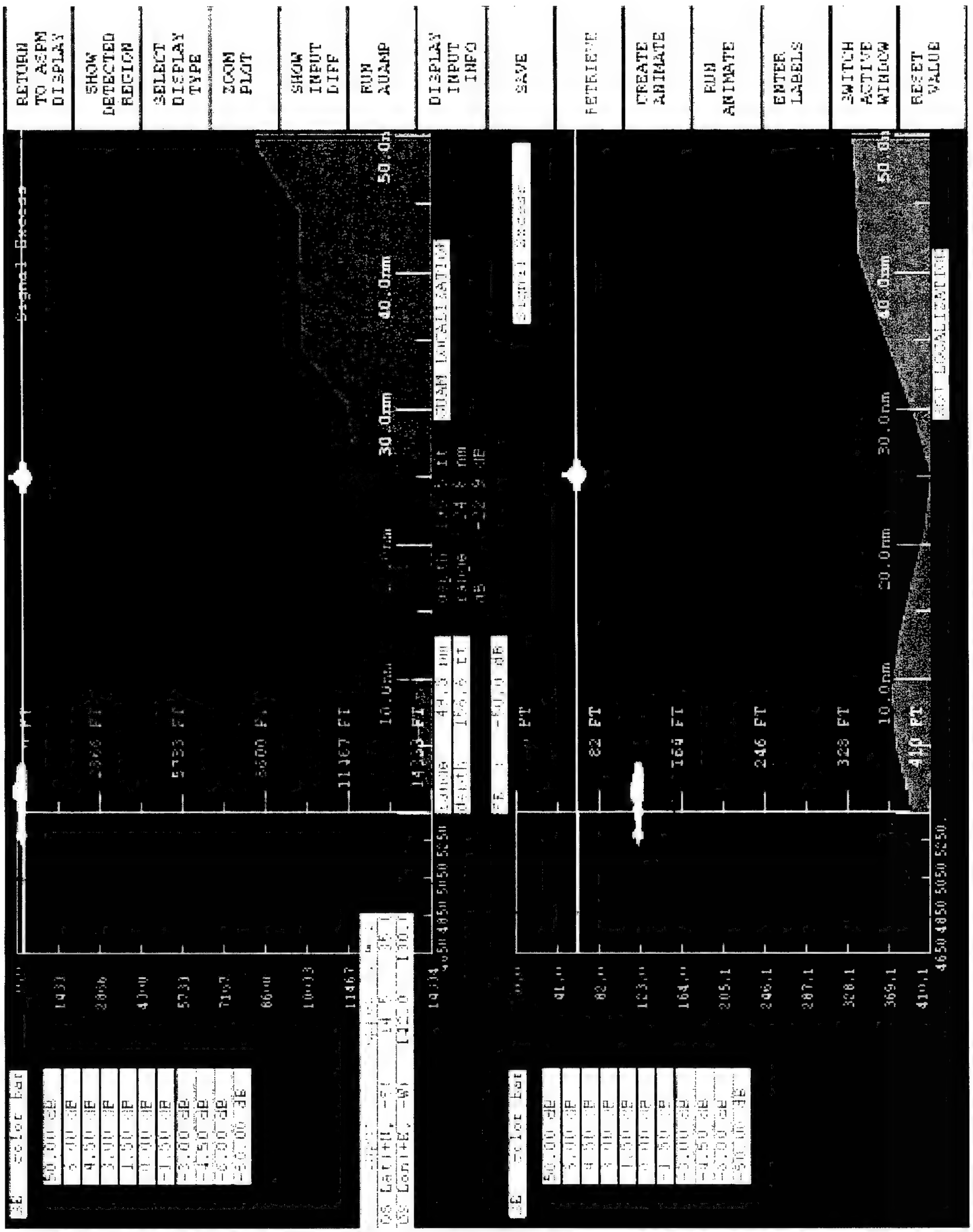


Figure A-9. Echo/noise/reverb.

Note. Refer to Figure A-10. Plan view.

The Plan View display allows us to look at the azimuthal variability of active sonar performance using the display formats we have previously introduced. Using the same data as for Figure A-7, we can present the comparison of seasonal performance as a function of azimuth. Any data set can be shown in the Full Field View or in the Plan View.

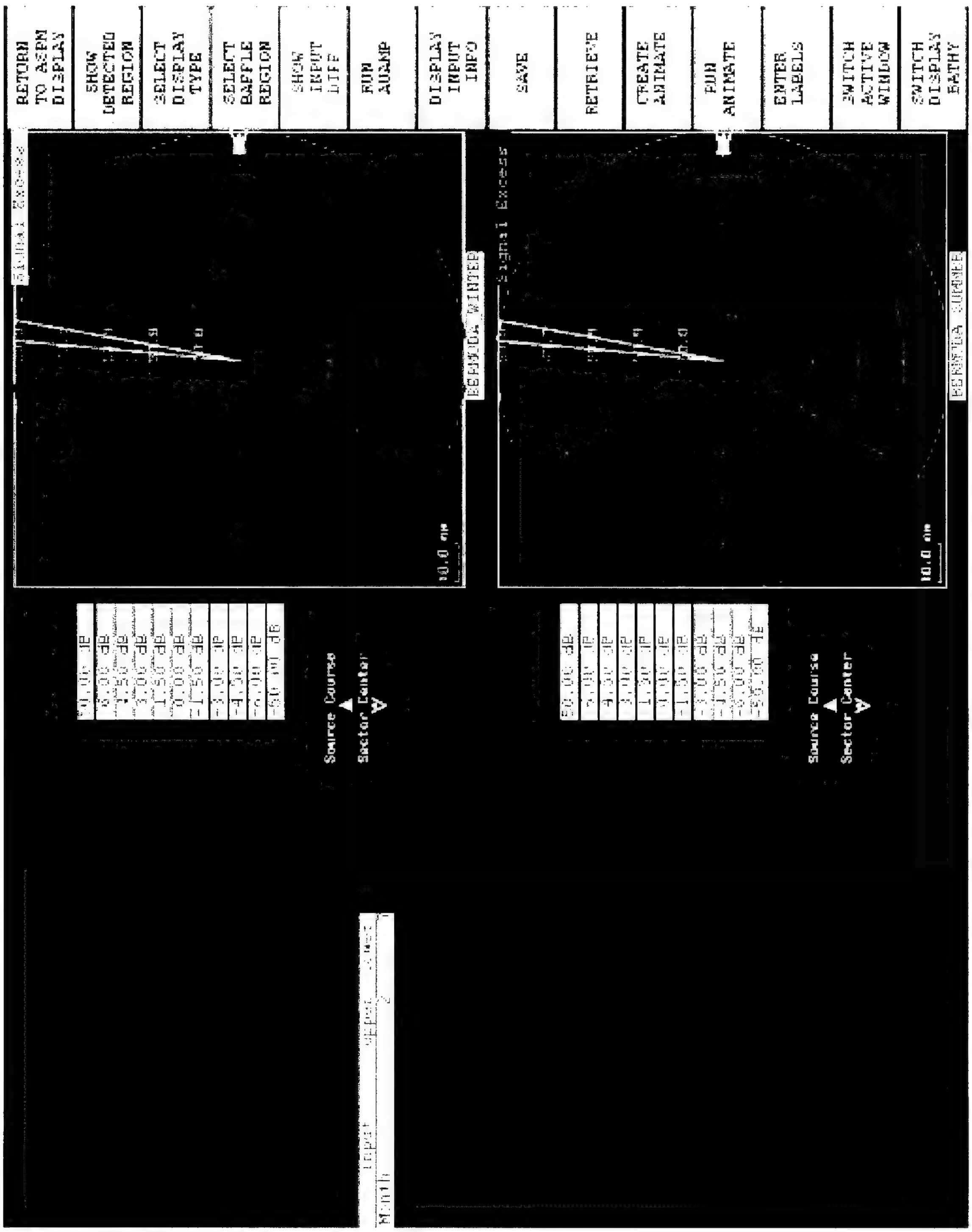


Figure A-10. Plan view.

Appendix B

Physics Review

Physics Review

General

The plan view plot has 72 sectors. The number of sectors has been hardwired. Any software changes to the number of sectors needs to take into consideration the effect on the representation of the transmit pattern. The calculation is performed along one radial in a 5 degree sector and is assumed to be valid for the entire 5 degree sector.

Transmission Loss

The peak TL, not the total TL, is displayed. The peak TL is the minimum transmission loss within the time resolution of the signal (1/bandwidth). Although TL changes as a function of bandwidth in the current implementation, this would not be a good comparison.

Reverberation

The reverberation curve does not accurately represent the temporal characteristics of the reverberation field. Discrete arrivals are not shown. This is because the AUAMP model is a single path model, which means that it sums all of the arrivals from a single reverberation path and attributes these to one arrival time (the time of the dominant arrival). In a real ocean environment, reverberation from an area may take a number of different paths, arriving at the receiver at different times. This effect is more significant at short ranges.

The components of beam reverberation are calculated using the following equation:

$$RL_{type} = SL - 2TL + SS + 10\log(\text{Area}) + 10\log(\text{RCV Horiz. Width})$$

where type is the bottom, surface, or volume beam reverberation. All three types vary as a function of source level and pulse length. The scattering strength term associated with each type of reverberation is discussed below.

The bottom scattering strength term, SS, is modeled as:

SS = bottom backscattering coefficient + 10 log [sin (grazing angle)]**2.

The bottom backscattering coefficient is the user input Bottom Scat Strn. The default value for this input is -27 dB/SY. The grazing angle is determined by the model and is related to the area propagation conditions and the user input D/E angle. A change in the bottom backscattering coefficient or the source level will result in a direct change in the level of the curve; the shape of the curve will not change. A direct change means that a change in the variable of 10 dB would be seen as a 10 dB change on the reverberation curve. A change in the pulse length will result in a direct change in the level of the curve; the shape of the curve will not change. The change in level of [10 log (puln 2) - 10 log (puln1)] will be seen, where puln2 is longer than puln1. For example, a change in the reverberation level as a function of a change in pulse length could be calculated as follows:

change from 250 ms to 500 ms.
puln2 = 10 log (500) = 10 log (2*250) = 10 log 250 + 10 log 2.
puln1 = 10 log 250.
the difference is a change of 10 log 2 or 3 dB.

A change in the source D/E will result in a change in the reverberation levels and shape of the curve. Unlike a change in SL, the change in the level of this curve will not be seen as a straight dB offset. The resultant curve is a function of a change in transmission loss to the bottom boundary and also 10 log [sin (grazing angle)]**2.

The surface scattering strength term is dependent on the following variables: frequency, wind speed, and grazing angle. A change in wind speed or frequency will affect the level and shape of the surface reverberation curve. An increase in either of these variables will result in an increase in surface reverberation. Changes in source level, pulse length, and D/E angle affect surface reverberation in the same manner that they affect bottom reverberation.

Volume reverberation is indirectly modeled as a function of the type of scatterer (through the selection of a scattering strength) and frequency (assuming that the value for scattering strength was chosen for the frequency of interest). A change in the volume scattering strength value results in a direct change in the level of the curve but does not result in a change in the shape of the curve. The more negative the volume scattering strength, the lower the resulting volume reverberation. A user defined volume scattering depth should be chosen after a consideration of SVP features. Diurnal migration of the deep scattering layer (DSL) can be shown by changing the depth appropriately. As with bottom reverberation, an increase in the source level or pulse length will change the level of the curve directly but not the shape of the curve. A change in D/E angle only indirectly affects volume reverberation through a change in transmission loss.

Banding in ASTRAL Full-field Plots

In environments where ducts exist, the ASTRAL model provides a solution for ducted energy that is somewhere between a full-wave solution such as that from PE, and a non-leaky mode solution. The approach taken produces results that, when plotted as a full-field TL vs. range and depth display, can look disconcerting.

In explaining the ASTRAL approach to duct propagation, we will first touch on the non-leaky and full-wave solutions.

The non-leaky mode solution would provide for energy within the duct and none below. In this case, propagation loss as a function of depth for a single mode would appear as shown in Figure B-1.

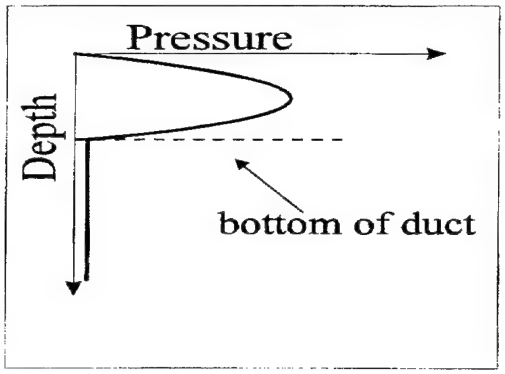


Figure B-1. Non-leaky mode solution.

Pressure varies within the surface duct and is zero outside the duct. The total field is the sum of all of the modes, so in a case where only modes that exist are ducted, the total field pressure will be non-zero *only* within the surface duct.

In a full-wave solution, every ducted mode leaks to some extent, continuously in range. This can be pictured as a series of rays that split at the bottom of each cycle into a ray that returns back into the duct and a ray that leaks across and ends up below the duct, as illustrated in Figure B-2.

The amount of energy that leaks into the deep cycling paths shown to the right depends on the strength of the duct, and on the mode number. Well-trapped modes in strong ducts have very little energy leak into the water column below the duct. This effect is modeled properly by equations such as PE.

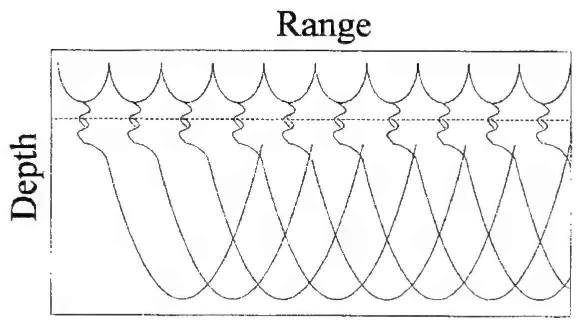


Figure B-2. Full wave solution.

ASTRAL is based on normal modes and the WKB approximation to normal mode theory, which accounts for part of its great speed. It gives up, however, the ability to compute a leaked mode field. Nevertheless, ASTRAL attempts to approximate the amount of energy that is leaked by each mode, and then makes the assumption that the energy is distributed evenly throughout the water column below the duct. On average, this is not a horrible assumption. In the ray diagram shown above, the deep-cycling leaked energy reaches most of the water column without any special range coverage.

The ASTRAL model assumes a duct profile similar to but reduced in level from the non-leaky case, and distributes the rest of the energy uniformly in depth below the duct, down to a depth where the sound speed exceeds the sound speed maximum in the duct (the reciprocal depth of the layer depth).

One example of where this approach will produce a noticeable and possibly disturbing effect is in a full-field plot of ASTRAL propagation loss as a function of range and depth. As an example, consider an environment with a surface duct above a negative-gradient sound speed profile and an absorbing bottom, as shown in Figure B-3. Below the duct, the field intensity will be the sum of all of the mode leakages, since there are not propagating modes below the duct (once they have all

been wiped out by the bottom). Each mode's duct leakage at any depth below the duct is the same as at any other depth, so the sum of all mode leakages will be independent of depth as well. Therefore, the field below the duct will be a function only of range, and will drop off with volume attenuation, bottom loss, and cylindrical spreading. Vertical banding will appear in any contour plot with discrete color changes. For example, if the full-field color palette matches a single color with a 3-dB band of propagation loss values, there will be a vertical band every "3 dB" in range.

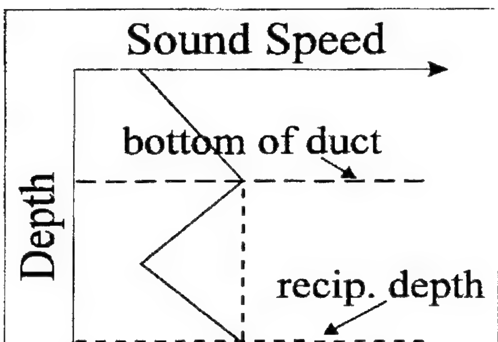


Figure B-3. Example of surface duct above a negative gradient sound speed.

A second example of the banding effect, as shown in Figure B-4, can be seen in environments where ducted and CZ energy coexist. Between CZs, deep shadow zones will be filled with leaked ducted energy, which will again show the banding effect. Where CZ energy is seen, it will generally overshadow the banded leaked energy.

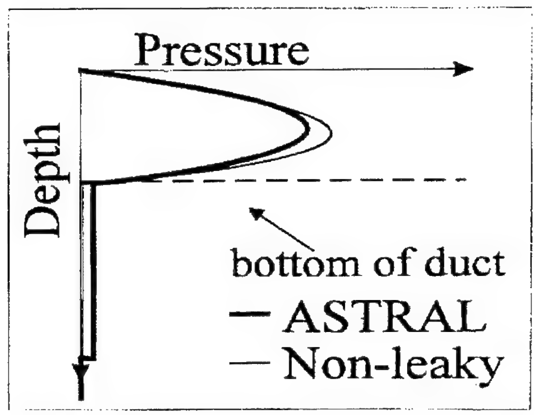


Figure B-4. Example of banding effect.

Appendix C

Active Performance Predictions Software

Introduction

This section discusses the AUAMP software and how it fits into the IMAT system. It provides a link between the current ASPM documentation and the modified AUAMP code resident in the IMAT system. Documentation referenced in this section includes the Software Design Description for ASPM and the ASPM User's Guide.

An underlying goal of the IMAT AUAMP development effort was to keep the configuration managed software intact whenever possible while creating the IMAT interface and providing enhancements. The major enhancement was the full field processing which required the addition of several new files to process multiple depths through the water column.

The following sections provide a framework for a developer maintaining this software by describing the software architecture, the input and output of the model, running stand-alone or as part of IMAT, and system cleanup.

Directory Structure

AUAMP code is divided into two major areas, the source and executable. The executables are created in the source directory but stored in a unique bin directory allowing the IMAT display code to spawn the executable upon request by the operator.

The directory structure for the ASPM source code has not been altered from the configuration managed software developed by SAIC. It resides under the */usr/imat/src/auamp/src* directory. Please refer to the ASPM SDD for a full list of the source directories. Those directories requiring AUAMP modifications are listed below.

/usr/imat/src/auamp/src/asert221 - the transmission loss model
/usr/imat/src/auamp/src/reverb - the reverberation model
/usr/imat/src/auamp/src/seamount - reads the seamount databases
/usr/imat/src/auamp/src/beamform - the beamform model
/usr/imat/src/auamp/src/soneq - the sonar equation model
/usr/imat/src/auamp/src/aspm_lib - a collection of common routines

Most of the ASPM code is written in FORTRAN but the utilities such as the I/O routines and the top level shell routines that are used by IMAT are written in C. Each of the above directories, excluding the aspm_lib directory, contains a subroutine, read_data.c, that reads the input data entered by the IMAT user and provides the interface to the ASPM code.

Each directory contains a 'makefile' that performs the compilation of both FORTRAN and C files, stores the data in a unique library located in the same directory, and creates an executable that is stored in the directory, */usr/imat/auamp/bin*. The libraries include asert.a, beamform.a, reverb.a, and active.a. The executables are asert, reverb, beamform, and se_active and are discussed in the stand-alone section.

Data Files

This section discusses the input file required by AUAMP and the output files created during an AUAMP model run. Only the actual input file created by IMAT is included. For a list of databases required by the model please refer to the ASPM SDD.

The input data file, *indata*, (Figure C-1) is created by the display process when the user selects RUN AUAMP from either the full field or plan view active displays. The indata file provides the model with all required variable data. This file has been modified several times to provide greater flexibility by the operator. It should be modified with caution because changes generally make all previously created run data files obsolete. This means that any lesson scripts and demos will have to be rerun.

```
7             month
22.0          lat
-160.0        long
15.0          wind(kts.)
400.0         vdepth(ft.)
67.0          vbscd
-27.0         bbscd
75.0          ambnoise(dB)
10.0          thr_speed(kts.)
90.0          tgt_heading(degs)
10            thr_strength(dB)
400.0         thr_depth(ft.)
10.0          sr_speed(kts)
400.0         sr_depth(ft)
0.0           sr_course(degs)
245.0         sr_level(dB)
705.0         freq(Hz)
0.25          puln(secs)
1             num_pings *
1             m *
1             n *
10.0          bandwidth
50.0          max_range(nmi)
0.0           radial_bearing(degs)
0.25          range_step(nmi)
7.5           rcv_vsteer(degs)
10.0          src_vwidth(degs)
8.0           rcv_vwidth(degs)
110.0         src_hwidth(degs)
5.0           rcv_hwidth(degs)
0.00100       slobe(power_ratio^.5)
4             mgs(hf_bottom_loss_province)
4             array_type(3=omni,4=cyl_array)
0             beam_pattern(do_not_change) *
72            num_radials *
10.000000     detection_threshold
0             class

* default
```

Figure C-1. AUAMP input file.

Data files are created at run time in the */usr/imat/auamp/bin* directory upon execution of a script called *newauamp* which is discussed under the stand-alone processing section. The original naming conventions have been preserved and carried over in the creation of the new files. Table C-1 lists all files created during a run. The new files include the TL, Echo, and Signal Excess files at one radial, T1R, T1S, EC1, and SE1, the components of reverberation, SR1, SU1, and VL1, and the beam reverb in range (vice time), BRR. Not all of the files created during a run are required for display purposes but are required for the duration of the full model run, i.e., seamount through signal excess.

Table C-1

AUAMP Output Files

Model	File Generated	Description	Display Type
Seamount	SRG000.GEN	Sorted seamounts	
Asert - (src to target)	DAS0100.GEN	Diagnostic	
	EVS0100.GEN	Environment	
	TLS0100.GEN	TL - 1 depth, 72 radials	Plan View
	T1S0100.GEN	TL - 108 depths, 1 radial	Full Field
Asert - (Rcv to target)	DAR0001.GEN	Diagnostic	
	EVR000.1GEN	Environment	
	TLR0001.GEN	TL - 1 depth, 72 radials	
	TIR0001.GEN	TL - 108 depths, 1 radial	
Asert - (Direct blast)	DAD0101.GEN	Diagnostic	
	EVD0101.GEN	Environment	
	TLD0101.GEN	TL	
Revert	BTR0101.GEN	Bottom reverb density	
	COM0101.GEN	Composite reverb density	
	DBL0101.GEN	Direct Blast	
	DIS0101.GEN	Seamount density	
	ECH0101.GEN	Echo - 1 depth, 72 radials	Plan View
	EC10101.GEN	Echo - 108 depths, 1 radial	Full Field
	VLR0101.GEN	Volume reverb density	
	SER0101.GEN	Seamount reverb density	
	SUR0101.GEN	Surface reverb density	
Beamform	BMR0101.GEN	Beam reverb	Echo/Noise/Reverb
	BMN0101.GEN	Beam noise	Echo/Noise/Reverb
	BRR0101.GEN	Beam reverb in range	
	SR1	Bottom beam reverberation	Reverb Components
	SU1	Surface beam reverberation	Reverb Components
	VL1	Volume beam reverberation	Reverb Components
Soneq	SEX *	Signal Excess - 72 radials	Plan View
	SEI *	Signal Excess - 1 radial	Full Field

*Plotted Data Files.

Stand-alone Processing

The AUAMP executables, ASERT, REVERB, BEAMFORM, SE_ACTIVE, and SEAMOUNT, are stored in the */usr/imat/aump/bin* directory. A stand-alone run can be started from this directory as long as the file *indata* is present. (Refer to Section 3 for a full description of the input data file.) This file is an ASCII file that is easily modified for testing purposes. To spawn the executables, use the shell script, *newauamp*, which contains the run commands in the proper order with the correct parameters. This is the same script that is called from the IMAT display code.

All executables are created for use with the debug tool, dbx. To perform a debug run, use the newauamp script to extract the input parameter stream needed for the executable of interest. For example,

```
dbx asert
run "GEN" "SRC" 1 1 B "NO*GBM" 0 1
```

A debug run must be performed in the same sequence as presented in the newauamp script. When testing a particular model and a rerunning of the model is required, use Figure C-2 to delete files created by the executable during the last run. For example, if testing beamform, all files prior to BMR0101.GEN on Table C-1 need to be preserved while all files including and following it should be removed.

```
cd /usr/imat/auamp/bin
source aspm.config
echo "setup environment"
echo "Removing all old files"
/usr/imat/auamp/bin/cleanamp
echo "Running the seamount extraction routine"
/usr/imat/auamp/bin/seamount
echo "Running asert for source to target TL - FF RUN"
/usr/imat/auamp/bin/asert "GEN" "SRC" 1 1 B "NO*GBM" 0 1
echo "Running asert for target to receiver TL - FF RUN"
/usr/imat/auamp/bin/asert "GEN" "RCV" 1 1 B "NO*GBM" 0 1
rm EV*
echo "Running asert for source to target TL - PV RUN"

echo "Running asert for target to receiver TL - PV RUN"
/usr/imat/auamp/bin/asert "GEN" "RCV" 1 1 B "NO*GBM" 0 0

echo "Running asert for source to receiver TL"
/usr/imat/auamp/bin/asert "GEN" "DIR" 1 1 B "NO*GBM" 0 0
echo "Running the reverberation model"
/usr/imat/auamp/bin/reverb "GEN" "RCV" 1 1 "NO*GBM" 0
echo "Running the beamform model"
echo "Creating symbolic links"
ln -s BTR0101.GEN BTR
ln -s SUR0101.GEN SUR
ln -s VLR0101.GEN VLR
ln -s SER0101.GEN SER
ln -s DBL0101.GEN DBL
ln -s DIS0101.GEN DIS
ln -s ECH0101.GEN ECH
ln -s EC10101.GEN EC1
echo "Removing previous beamforming output files"
rm BMR
rm BMN
echo "Running beamform"
beamform
echo "Renaming beamform files"
cp BMN BMN0101.GEN
cp BMR BMR0101.GEN
echo "Overlay the newly created components of reverb files over the reverb density files "
cp VL1 VLR
cp SR1 SER
cp SU1 SUR
echo "Beamforming complete"
echo "Removing previous sonar equation output files"
rm PBR
rm SEX
rm PDT
echo "Running the active sonar equation model"
se_active

echo "AUAMP complete"
cd /usr/imat
```

Figure C-2. NEWAUAMP script.

IMAT Processing

IMAT uses the *newauamp* script described previously to run the auamp model from the */usr/imat/active/ff* or */usr/imat/active/astr* directories. It is called from the active_ff_fnctn.c and active_astr_fnctn.c routines residing in these directories. The AUAMP run files are created in the */usr/imat/auamp/bin* area as described in the stand-alone section and are not saved for future use unless a request by the operator is entered. Upon such a request the script, cpfile (Figure C-3) is invoked to save the data needed for plotting to the /usr/imat/data/active/ff directory with an operator specified prefix and a 3 letter extension describing the file, e.g., TLR0101.GEN becomes MYFILE.TLR. The indata file is also saved as MYFILE.indata. A single newauamp run will create all files needed to produce either full field or plan view displays.

The files copied by the cpfile script are used by the display process. The BRR file and either the TLS or T1S file for plan view and full field respectively are read upon each display attempt to extract header information. A list of active displays and the unique data files used by the display process is presented in Table C-2.

Table C-2

Active Display Required Files

Active Display Type	Required Files
Full Field 1-Way TL	T1S
Full Field 2-Way TL	T1S,T1R
Full Field Echo	EC1
Full Field Echo/Noise/Reverb	EC1,BRR
Full Field Signal Excess	SE1
Full Field Reverb Components	EC1,SUR,SER,VLR
Plan View 1-Way TL	TLS
Plan View 2-Way TL	TLS,TLR
Plan View Echo	ECH
Plan View Echo/Noise/Reverb	ECH,BRR
Plan View Signal Excess	SEX
Plan View Reverb Components	ECH,SUR,SER,VLR

In addition to the files created by the model, the display code also creates files which are stored in the */usr/imat/data/active/ff* directory. These files are generated when the user creates an animation or saves the current settings of a display for future call up.

```
echo "in /usr/imat/auamp/bin/cpfile $1 "
cd /usr/imat/auamp/bin
#replace old TLS and TLR for full field
cp T1S0100.GEN          /usr/imat/data/active/ff/${1}.T1S
cp T1R0001.GEN          /usr/imat/data/active/ff/${1}.T1R

# for 72 radials
cp TLS0100.GEN          /usr/imat/data/active/ff/${1}.TLS
cp TLR0001.GEN          /usr/imat/data/active/ff/${1}.TLR

# for 72 radials
cp ECH0101.GEN          /usr/imat/data/active/ff/${1}.ECH

#for 1 radials for full field
cp EC10101.GEN          /usr/imat/data/active/ff/${1}.EC1

#for ambnoise and reverb io format BMR
cp BRR                  /usr/imat/data/active/ff/${1}.BRR
cp SUR0101.GEN          /usr/imat/data/active/ff/${1}.SUR
cp SER0101.GEN          /usr/imat/data/active/ff/${1}.SER
cp VLR0101.GEN          /usr/imat/data/active/ff/${1}.VLR

#replace se.dat for plain view of 72 radials
cp SEX                  /usr/imat/data/active/ff/${1}.SEX

#replace SEX for full field
cp SE1                  /usr/imat/data/active/ff/${1}.SE1
cp indata               /usr/imat/data/active/ff/${1}.indata
chmod 777               /usr/imat/data/active/ff/${1}.*
```

Figure C-3. CPFILE script.

Two steps are required in creating an animation. First, a multiple data set run is made which generates a file by a user supplied name with the extension, *.srp.* This srp file provides the number of files in the animation and the prefix name of each file run. Second, the actual animation is created with the current display settings and the multiple data set name used. This procedure generates a file named by the user with a *.anf* extension when in full field and an *.ana* extension when in plan view. Refer to section 5.6 for a complete description of animations.

Current settings are created in a similar fashion to the animation creation. Once the user is satisfied with the display and saves it as CURRENT SETTINGS, a file is generated and named by the user with a *.dsp* extension when in full field and an *.astr* extension when in plan view. This file saves current setting flags which include upper and lower settings for display type, zoom mode, labels, the names of the files used to generated the display, and whether a list of inputs or input differences will be displayed.

System Cleanup

Due to the number of files generated by an AUAMP run and especially the size of a multiple data set run, the system may run out of hard disk space and unwanted data files may have to be removed. This can be done by going to the directory and manually deleting files, which assumes the user knows exactly which files to delete. A better way is to use the IMAT system which performs checks on animation and current setting files to assure that they are not pointing to files requested for deletion.

Deletion options are as follows:

- Data set This includes all files from one run. A list of all .indata files is presented to the user. If a data set is chosen that is used in an animation or current settings, the user will be warned and asked if the deletion should continue. If the user selects to continue the animate or current setting file using the data set will also be deleted to avoid errors if called up in the future.

- Display type A list of all .indata files is presented to the user. Upon file selection, the user is presented with a list of display types that may be deleted without affecting an animation or current settings. Files are coupled when deletion of one effect more than one display.

FF 2-WAY TL	- deletes T1R
FF ECHO/ENR	- deletes EC1
FF SE	- deletes SE1
PV 2-WAY TL	- deletes TLR
PV ECHO/ENR	- deletes ECH
PV SE	- deletes SEX
COMPONENTS OF REVERB	- deletes ECH,EC1,SUR,SER,VLR

- Animations A list of all .ana or .anf files is presented to the user for deletion.

- Current Settings A list of all .dsp or .astr files is presented to the user for deletion.

An active file cleanup also takes place upon exiting the IMAT system if the user is running from the GUEST account. This process will delete all active files that are not coupled to an animation or current settings. The user is prompted before the deletion and given the chance to override.

Other space saving measures provide the user with the choice of saving active files to an optical drive.

Distribution List

Chief of Naval Operations (C92L1), (N879), (N869), (N889F6), (N71)
COMNAVAIRSYSCOM, Program Manager, Aviation Training Systems Program Office (JP1) (PMA205)
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